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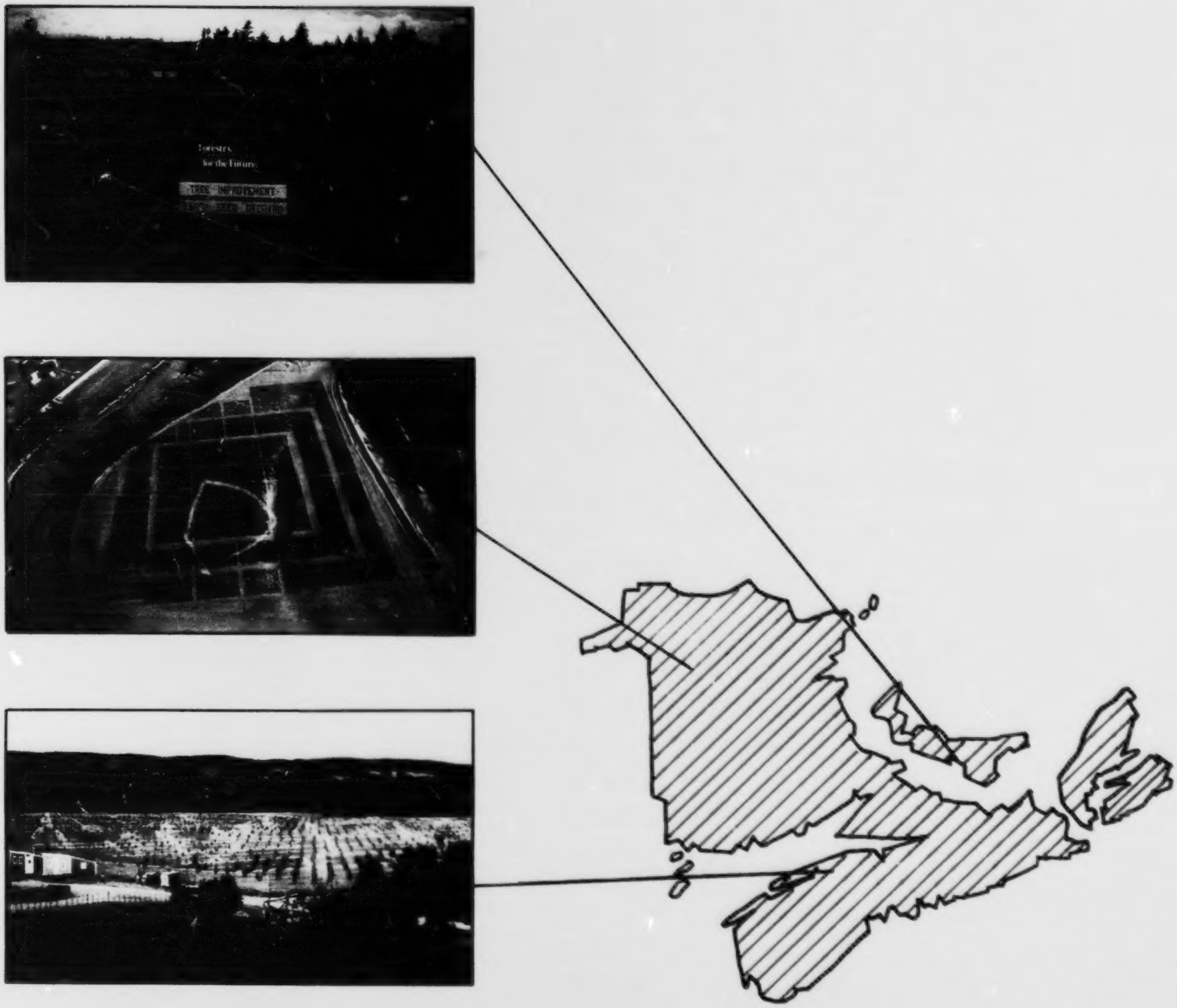
A manual for forest tree seed orchard management in the Maritimes

J.D. Simpson and R.F. Smith

Information Report M-X-167

Canadian Forestry Service - Maritimes


Forestry
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TREE IMPROVEMENT
LARCH SEED ORCHARD

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Cover photographs:

TOP:	Tamarack clonal seed orchard, P.E.I. Forest Service
MIDDLE:	Black spruce seedling seed orchard, Fraser Inc.
BOTTOM:	Red spruce clonal seed orchard, Bowater Mersey Paper Company

A MANUAL FOR FOREST TREE SEED ORCHARD MANAGEMENT IN THE MARITIMES

by

J.D. Simpson and R.F. Smith

Information Report M-X-167

Government of Canada

Canadian Forestry Service - Maritimes

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ABSTRACT

Procedures are outlined for the establishment and management of seed orchards in the Maritime provinces. Sections are included on site selection and orchard site planning, site preparation, orchard design, layout and planting, control of competing vegetation, fertility management, protection, cone-crop enhancement, and cone harvesting.

RÉSUMÉ

Ce manuel indique les méthodes à suivre pour bien établir et aménager les vergers à graine dans les provinces Maritimes. On y trouve des sections traitant de la sélection et planification des sites des vergers, préparation des sites, plans détaillés de vergers et leur disposition sur le terrain, plantation, suppression de la végétation concurrentielle, techniques d'amélioration de la fertilité, protection, augmentation de la production des cônes, et récolte des cônes.

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PREFACE

Increased emphasis on intensive forest management in the Maritime Provinces is a result of increasing demand for wood products and the rapidly shrinking supply of sawlogs and pulpwood. One of these intensive management techniques is reforestation with genetically improved planting stock. In the Maritime Provinces, cooperative tree improvement programs involving industry, federal and provincial governments, and the University of New Brunswick are in operation. The programs are based on the selection of individual trees exhibiting desirable characteristics, establishing seed orchards and testing the selected trees or their progenies to determine which should be retained for seed production and future breeding. Genetically improved seed obtained from these orchards will be used for the reforestation programs in the Maritimes.

The techniques used to plan, establish, and manage a seed orchard vary with the species involved and the stage in the breeding program. In the Maritimes, for example, first generation seed orchards for black spruce (*Picea mariana*[Mill] B.S.P.) and jack pine (*Pinus banksiana* Lamb.), are seedling orchards while second generation orchards will be clonal. First and subsequent generation orchards for most species will be clonal.

This manual outlines in detail, the steps required for planning, establishing, and managing tree seed orchards in the Maritimes Region. The information is the best available, at present, but will undoubtedly be updated as more knowledge is acquired.

CHAPTER 1

PLANNING

Forest tree seed orchards are expensive to establish and manage and require continuous funding. Therefore, careful planning of such a facility is necessary to ensure that funds are continuously available. The planning process involves the selection of a suitable orchard site and the development of detailed site plans incorporating soil, topography, and area requirements for seed production, pollen dilution, firebreaks, roads, and windbreaks.

Site Selection

Seed orchards are sound investments only if they are fully productive. Environmental and edaphic variables of site influence seed production so care must be taken to choose a site on which seed production will be maximized. A well chosen site can also minimize management problems. Twenty-five years of experience in British Columbia and the southeastern United States indicates that location is crucially important in achieving abundant and frequent cone crops.

General location

Seedling seed orchards

For about the first 15 years after planting, seedling seed orchards are used to evaluate the performance of selected families (when rogueing) and to produce seed. The decision as to which trees will be retained in a seedling orchard, after entire families are rogued using family test results, is based, in part, on their performance in the orchard. Consequently, seedling seed orchards should be established on good sites, that are deemed conducive to cone production and within the range of 'typical' planting sites for the species. They should be located within the region where the future improved planting stock will be used.

Clonal seed orchards

The sole purpose of a clonal seed orchard is to produce genetically improved seed. Clonal orchards must be located on sites and in environments that maximize seed production. It is known that trees growing on sites with southerly aspects and in areas with warm, dry, and sunny summer climates generally produce more cones than those growing on north slopes and in cold, wet areas (Sarvas 1970; Schmidtling 1979; Werner 1975). Coles (1980a) analyzed the climatic data for the Maritimes and identified the Annapolis Valley of Nova Scotia, the southeast area of Prince Edward Island, and southwestern New Brunswick as having suitable climates for establishing clonal seed orchards (Fig. 1-1), although there are also other suitable areas.

Specific location

Clonal and seedling seed orchards

Soils. Texture strongly influences soil structure, erodibility and compactibility and because it is essentially unchangeable, it must be given high priority when selecting an orchard site. A deep (30 to 50 cm) zone of sandy loam to loamy sand overlaying a friable subsoil presents the fewest problems with drainage and compaction. Heavy clay soils must be avoided because compaction problems will result from the heavy and frequent traffic in the orchard. Excessively drained sandy soils should also be avoided because fertility levels will be difficult to maintain (low cation exchange capacity) and trees will be prone to severe water stress during dry weather.

A detailed soil survey should be conducted before selecting the location of a clonal seed orchard (see APPENDIX I, Fig. I-1). Geological and soil survey maps should be obtained for the area being evaluated. These provide excellent background information about the soils that might be found on site and they help to interpret what is actually found once the soil is examined. A detailed discussion on evaluating and managing seed orchard soils is given in CHAPTER 5. A series of soil pits should be dug, to assess soil characteristics such as rooting depth, soil texture, soil nutrients, the presence of compacted or hardpan layers, and evidence of poor water drainage, e.g., soil mottling. Each soil pit should be 0.5 to 1 m deep with the depth being determined by the soil depth, depth to bedrock, etc. The number of soil pits to be dug in a given area will vary with the uniformity of the site, but normally one or two per hectare is sufficient. A quick method for digging these soil pits is to use a soil auger (40-45 cm diameter) run on the power take-off of a farm tractor. The pits for a 20- to 40-ha site can be dug in one day using this system if most of the site is accessible. The soil evaluation is supplemented with fertility samples (see CHAPTER 5, Soil Sampling).

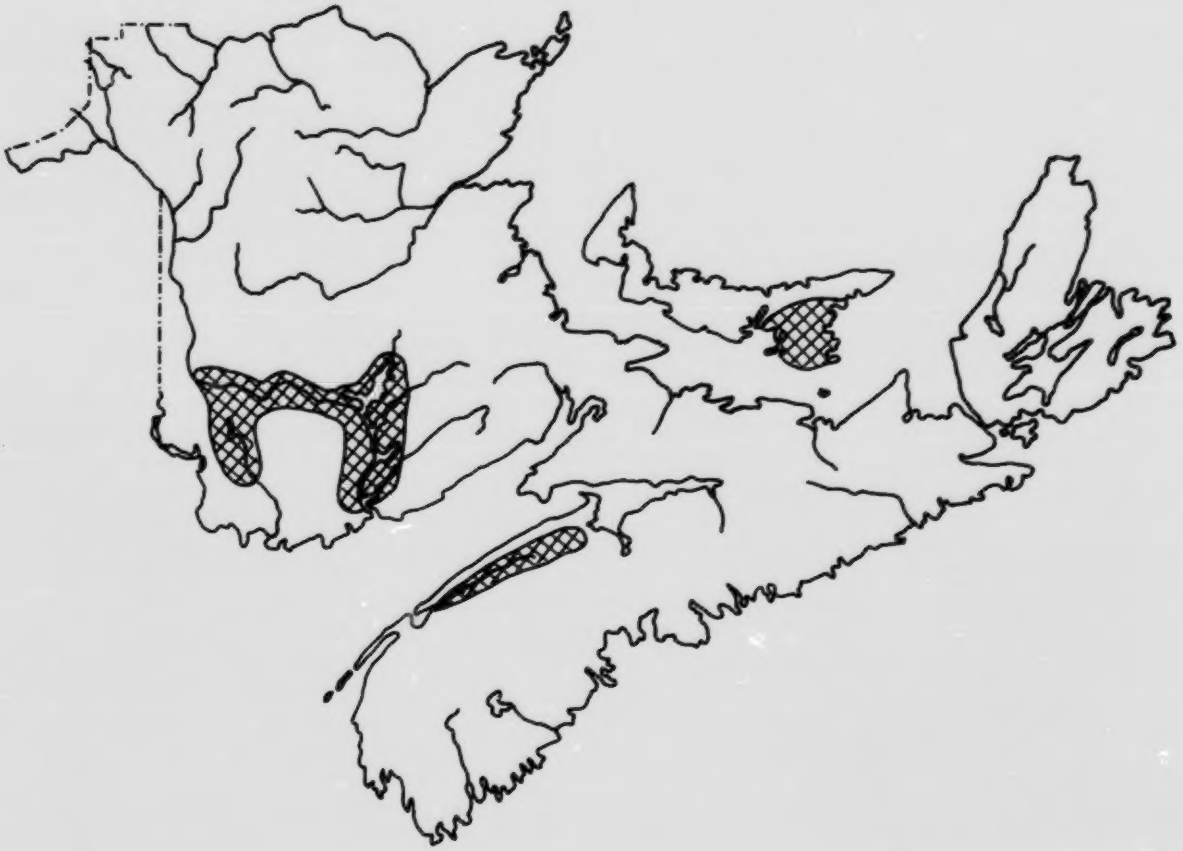


Figure 1-1. Recommended areas for establishment of clonal seed orchards in the Maritimes (from Coles 1980a).

Adequate soil drainage is necessary for on-site accessibility in the spring and after heavy rains. It is also important for the development of a deep and extensive root system. Soil drainage should be evaluated, and improvements (e.g., drainage tile, ditches) made before the orchard trees are planted (APPENDIX I, Fig. I-2). NOTE: Correcting a soil water drainage problem 10 years after planting is virtually impossible without seriously damaging many of the orchard trees.

The best time of year to determine if there are drainage problems is in the early spring following snowmelt or after heavy rains. Ponding of water in depressions can be noted and the time required for this water to soak into the soil should be monitored. If water remains on the surface more than a day following a heavy rain, artificial drainage will be required.

Topography. The topography of the site influences insolation, air and water drainage, and ease of equipment movement. Topography is also essentially unchangeable, and is therefore an important consideration when selecting a seed orchard site. Select a site with a gentle (<5%), uniform slope. A pit-and-mound topography is undesirable. Trees must not be planted in hollows or depressions into which water drains. Planting in 'wet' pockets will adversely affect tree survival, growth, and cone production (see APPENDIX I, Fig. I-3).

Insolation. In the northern hemisphere, south facing slopes receive the greatest amount of direct insolation, consequently they are warmer. Simpson and Powell (1981) found that young black spruce trees growing on south-facing sites produced more cones than those growing on sites with other aspects.

Air drainage. Frost pockets must be avoided because conifer strobili are very susceptible to damage by late spring frosts. Do not locate a seed orchard at the base of a hill or in a depression where cold air will settle. Gently sloping sites with good air drainage will be less likely to receive 'killing' spring frosts than completely flat sites from which air does not drain readily.

Accessibility. The orchard must be accessible and operable during all seasons of the year particularly in early spring. In seedling seed orchards, stumps can pose a problem for early mechanized cone collection. A well kept road system MUST be maintained. It is advantageous to locate an orchard near a nursery or field office. A close source of manpower and equipment facilitates monitoring the orchard and helps control access.

Isolation from foreign pollen. An orchard should be located on a site where contamination by pollen of the same or closely related species is minimal. Locating seed orchards either outside the natural range of the species or in a warmer climate where the orchard trees are out of phase with the local trees have been suggested as potential solutions to the pollen contamination problem (Gansel 1973; Sarvas 1970; Werner 1975). In some areas of the Maritimes, it may be impossible to locate an orchard outside the natural range of a species such as white spruce (*Picea glauca* [Moench] Voss). Therefore, a compromise should be adopted such as locating the orchard as far as practicable from natural stands of the same species, removing trees of the same species from the surrounding areas, and locating orchards on warm sites.

Past land use. The history of a site being considered for an orchard should be known. For land previously farmed, it is vital to determine what chemicals, if any, have been used and to have the soil tested for potentially harmful residues. A potential orchard site may have to be rejected because of the past use of arsenicals or high residues of herbicides such as atrazine.

In the Maritimes, the only commercial laboratory for testing for herbicide residues is the Atlantic Provinces Pesticide Residue Laboratory in Kentville, Nova Scotia (see Shreve and McCarthy 1985). Testing for chemical residues is expensive ($120/chemical, M. Shreve, pers. comm. Nov. 1986).

Orchard Site Plan

Having selected a suitable site, a detailed plan encompassing all the long-range goals is necessary for a successful and productive orchard complex. The components of planning an orchard are discussed below. Although most items apply specifically to clonal seed orchards they also can be applied to seedling seed orchards. APPENDIX I, Fig. I-4 presents a general site plan, which should be made BEFORE orchard establishment begins.

Area requirements

There are many considerations in determining total area requirements, such as the number of orchards (if more than one) to be combined at one complex, and allowances for roads, drainage ditches, and ponds, equipment storage or maintenance areas, poor or unusable land, pollen dilution zone, firebreaks, and windbreaks. These could double the total area required for an orchard complex and must be considered during the planning and site selection stages.

Seed production

There is at least a 7 to 10 year lag between initiation of a tree improvement program and the production of quantities of genetically improved seed. Consequently, long-range planning of a reforestation program is a must. The area of seed orchard required must reflect the planting program 20 to 30 years hence.

The area of seed orchard necessary to produce sufficient quantities of seed for a particular species can be calculated. The number of seedlings required annually and the quantity of seed produced from a unit area of orchard need to be determined. There are, however, a number of other factors involved in estimating area requirements.

1. Seedling production system (bare-root vs. container).
2. Periodicity of cone crops.
3. Number of trees or grafts per unit area.
4. Number of cones produced per tree or graft.
5. Number of viable seed per cone.

Table 1-1 summarizes the actual area of orchard to be planted to produce one million plantable seedlings a year by species and is an updated version of a table found in Coles (1980b). APPENDIX II explains the assumptions and calculations. Two important points should be emphasized 1) cone production per tree is an estimate falling between early production and late production (time orchard is phased out) and 2) trees per unit area is the number after final rogueing. Hence, for clonal seed orchards, in particular, before rogueing, seed production will probably exceed those estimates presented here.

Table 1-1. Estimates of seed orchard area requirements (adapted from Coles 1980b)

Species Type of seed orchard (S.O.)	Number of cones/trees[1]	Sound seed/cone	Trees/ha (spacing)[2]	Interval between cone crops	Method of seedling production (S.S. - sound seed)	Area required for 1 million plantable seedlings/year (ha)
Black spruce Seedling S.O.	200	20	415 (6 x 4 m)	2	container 1.5 S.S./seedling	1.8
White spruce Clonal S.O.	200	30	275 (6 x 6 m)	2	container 1.5 S.S./seedling	1.8
Red spruce Clonal S.O.	200	25	275 (6 x 6 m)	2	container 1.5 S.S./seedling	2.2
Jack pine Seedling S.O.	75	25	415 (6 x 4 m)	1	container 1.5 S.S./seedling	1.9
White pine Clonal S.O.	200	40	275 (6 x 6 m)	3	container 1.5 S.S./seedling	2.0
Tamarack Clonal S.O.	600	8	275 (6 x 6 m)	2	container 1.5 S.S./seedling	2.3

[1] The number of cones per tree will increase with age and size. The figure given is an estimate which falls between early production and that of maturity of the orchard.

[2] The number of trees per hectare will decrease from establishment to maturity. The figure given represents the number remaining following final rogueing.

Pollen dilution zone

An orchard complex should be isolated from contaminating non-orchard pollen. This is especially important during the early stages of orchard development when little pollen is produced within the orchard. During later stages, 15-25 years, the mass effect of orchard pollen will reduce the effects of contamination. However, a dilution 'strip', where all trees of the same species as those planted in the seed orchard are removed, may be warranted. The effectiveness of such a strip is questionable because of the long distances wind-borne pollen can travel. A 500-m strip should be considered as a minimum. In addition, as many as possible nearby sources of contamination should be removed.

Firebreak

A firebreak around the outer perimeter of the orchard should be maintained free of trees and shrubs. This should be 15 to 20 m wide and, if the orchard is clonal, planted with grass that is kept mowed.

Roads

Easy access throughout the orchard is necessary. Major roads will normally separate the suborchards in a complex. Secondary roads will separate blocks within the suborchards and occur around the outer perimeter. A strip 10 m wide for major roads and 6 m for secondary roads (sufficient to accommodate equipment turning) should be allowed.

Pond

An orchard complex cannot be operated successfully without an adequate supply of water for irrigation, fire protection, chemical spraying, etc. The Atlantic Committee on Agricultural Engineering publication titled "Farm Ponds" (Higgins 1984) provides all the necessary information for pond construction and maintenance. About 0.5 ha should be allowed for a pond area near the centre of the orchard complex. An agriculture engineer from a provincial Department of Agriculture can assist in the planning and designing of a pond. Ponds constructed in the Maritime Provinces must also meet any specifications and regulations laid down by the appropriate provincial Department of Environment. A well or river is an alternate source of water.

Windbreaks

Windbreaks may be necessary to reduce wind velocity on large orchard sites to limit the drying effect of the wind during winter. Windbreaks also conserve moisture by reducing evaporation and transpiration in summer and by trapping snow in winter. Two or three rows of trees, planted in a staggered fashion at a 2.5 x 2.5 m spacing, should provide sufficient protection. A strip at least 10 m wide should be left between the windbreak and the orchard trees to allow for equipment turning and to reduce any shading effect of the windbreak on the orchard trees.

Equipment shed and offices

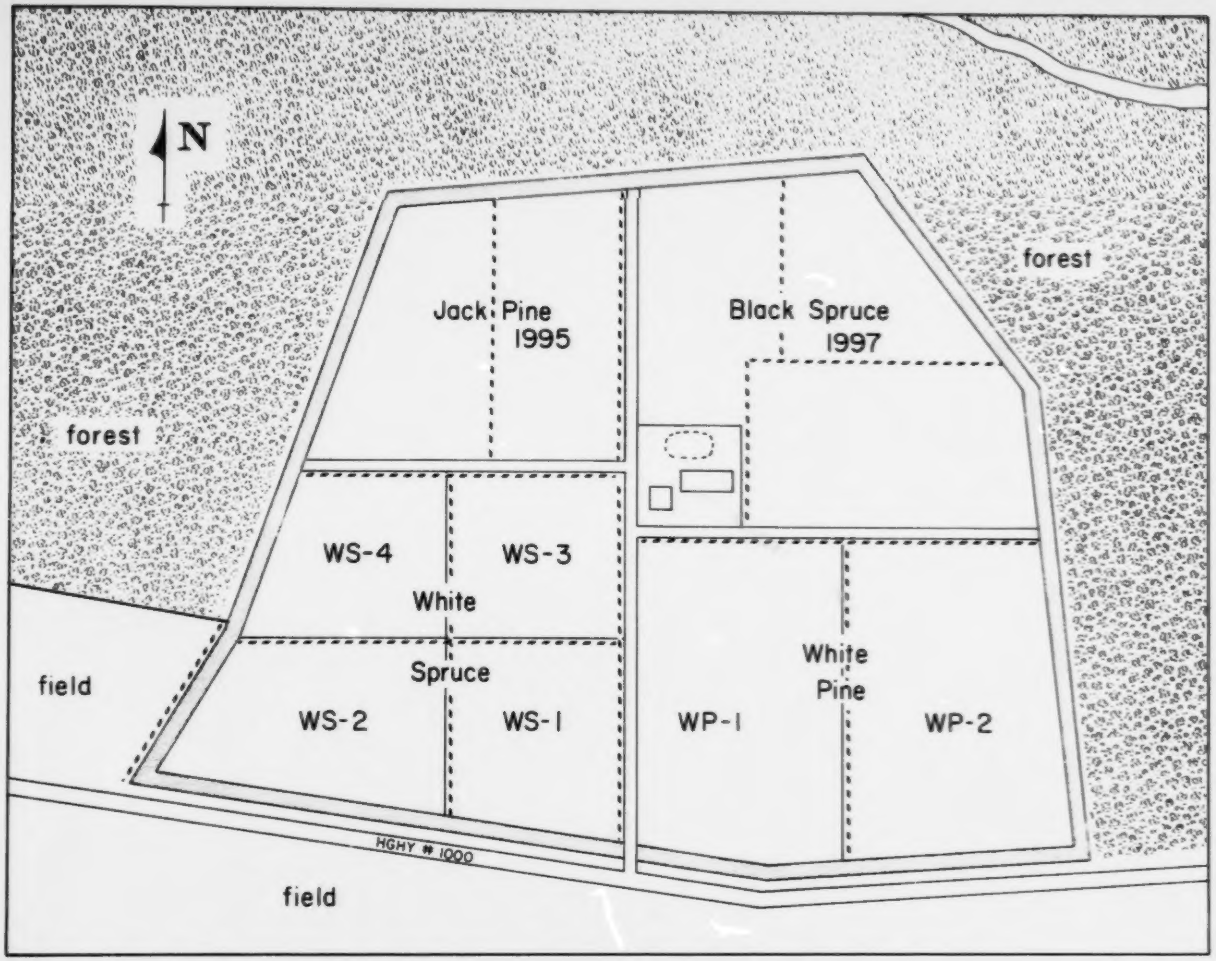
Depending on the size of the orchard complex or the proximity to existing facilities, it may be necessary to construct buildings for storing equipment and chemicals, offices, or a small laboratory for pollen and seed handling, and insect and disease detection. Proximity to a power supply is a must if such structures are to be built.

Layout

Once the areas required for the various components have been calculated, a map of the site incorporating the appropriate components (Fig. 1-2) should be drawn. The map should be drawn to scale and suitable to overlay other maps containing soil and topographic information, and drainage plans (see APPENDIX I, Figs. I-1 to I-3).

Suborchards

If an orchard complex containing several species is being considered, the positioning of the individual species in the suborchards should be considered. Each suborchard must be of sufficient size to produce enough pollen and to accommodate proposed expansion. The minimum size of a suborchard should be 3 to 4 ha and be arranged so that the prevailing wind at the time of pollination blows parallel to the long axis thus promoting within-orchard pollination. Species that readily hybridize (e.g., black spruce and red spruce (*Picea rubens* Sarg.) should not be planted in the same complex.


N
forest
forest
forest
Jack Pine
1995
Black Spruce
1997
WS-4
WS-3
White
Spruce
WS-2
WS-1
White
Pine
WP-1
WP-2
field
field
HGHY # 1000

KEY

1 cm = 25 m
Firebreak
Pollen Dilution Zone
Pond
Building
Main Road
Secondary Road
Windbreak

SUB ORCHARDS	
BLOCK	AREA (HA)
WP-1 WP-2	5.0 5.0
TOTAL	10
WS-1 WS-2 WS-3 WS-4	3.0 3.9 2.5 2.6
TOTAL	12.0
Black Spruce Jack Pine Pond Area	10.5 8.5 1.2
TOTAL	42.2

Figure 1-2. Clonal seed orchard site plan.

Roads

Major roads separating suborchards should be graded or at least kept surface-bare. They can double as firebreaks. Secondary roads within and around the suborchards are grassed. All roads should be as straight as possible.

Soil drainage

Areas where drainage appears to be a problem should be noted. Drainage may be improved easily during site preparation by subsoiling to break up a hardpan, installing drainage tile, or digging drainage ditches (see CHAPTER 2, Soil Drainage). If drainage on the site is to be 'properly' upgraded, a drainage plan must be made (see APPENDIX I, Fig. I-2). An agriculture engineer should be consulted for advice. Agriculture engineering and consulting firms throughout the Maritimes are capable of doing this work.

Windbreaks

Tree height is the most important characteristic of a windbreak because the distance that protection extends leeward is proportional to height. When wind direction is at a right angle to the long axis of the windbreak, windspeed to leeward can be significantly reduced for distances up to 20 times the average height of the trees (Dronen 1984). Windbreaks should be established along the windward side(s) of suborchard blocks. A fast growing species should be planted, one which provides year-round protection. Red pine (*Pinus resinosa* Ait.) or Austrian pine (*Pinus nigra* Arnold) (possibly seed sources from Austria, France, Spain, and Italy) are suitable because they are relatively fast growing and can form large, thick crowns when sheared. Other species such as white spruce, black spruce, and jack pine may also be considered, provided they are not species already planted in the orchard. Hybrid poplar may be used initially in conjunction with pine or spruce to produce a windbreak quickly but poplar should be avoided where tamarack (*Larix laricina* (Du Roi) K. Koch) is planted because it acts as an alternate host to a rust, *Melampsora medusae*, which infects tamarack.

Irrigation

An in-ground irrigation system probably will not be necessary in Maritimes seed orchards. If irrigation is required to delay strobilus development, prevent frost damage, or counteract drought, a moveable above-ground system can be used. Trickle irrigation systems are effective for watering and fertilizing trees and are cheaper than other systems. If irrigation is deemed necessary, a system should be devised in consultation with an agriculture engineer.

Consideration should be given to water quality. Irrigation water quality primarily depends upon its content of silt and salt constituents (Thorne and Peterson 1954). Table 1-2 gives some guidelines.

The soil testing laboratory at the Canadian Forestry Service, Fredericton can determine all quality characters listed in Table 1-2 except chlorine and sulphate. The soil and plant testing laboratory, Hugh John Flemming Forestry Centre, UNB Building, Fredericton has the capability to determine all quality characters. The soil analysis laboratory at the Nova Scotia Agricultural College, Truro can determine all quality characters except molybdenum and lead. The federal Department of Agriculture laboratory in Charlottetown can analyze water for all characters except aluminum and molybdenum. Conductivity is determined in the field at the time the water sample is collected.

Fencing

If serious problems from browsing animals are expected, or occur, fencing may be necessary. It is also useful to control access.

Table 1-2. Water quality criteria for irrigation[1]

Constituent	Content			Comments
	Good	Fair	Poor	
Dissolved solids		130 ppm		
pH	6	<7	>7	When above 7, check carbonates, bicarbonates and calculate the sodium adsorption ratio (SAR) and residual sodium carbonate (RSC)
Conductivity (micromhos)	<250	<750	>750	When above 250, check SAR and salinity hazard
Concentration of cations (ppm)				
K	-	-	-	Beneficial to plant nutrition
Ca[2]	120	-	-	Higher levels prevent P injection and increase precipitation in irrigation lines (see Fe)
Mg[2]	36	-	-	Higher levels increase precipitation problems
Na	<69	<184	>184	Can go as high as 184 ppm if K maintained at an equal concentration although 69 ppm can cause direct root or shoot injury
Concentration of trace elements (ppm)				
Fe	5.0			May cause precipitation of phosphates and clog nozzles
Al	5.0			This depends on the pH value. At low pH, 5 ppm may be harmful. Toxicity of Al and Cu also depends on the level of organic anions in the water
Mn	0.2			
Zn	2.0			
B	0.5	<2.0	>2.0	
Mo	0.01			
Pb	0.05			Drinking water standard
Concentration of anions (ppm)				
Cl[2]	<115	<350	>350	Can injure foliage
NO_3	10			Drinking water standard. Generally beneficial to plant growth
SO_4		<480		
CO_3	0	-	-	Check SAR, RSC. Significant amounts not present unless pH exceeds 8.5
HCO_3	0	<180	>360	Seriousness depends on pH. Causes precipitation of beneficial cations, resulting in greater danger from any Na contained in the water
Calculated indices				
SAR[3]	<10	<18	>18	
ASAR[4]	<3	>3	-	Indication of potential Na toxicity
ASAR	<6	<9	>9	Indication of soil permeability
RSC[5]	<1.25	<2.5	>2.5	

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[1] The values in this table are to be used as guidelines and in no way should be construed as absolute standards (R.D. Hallett, pers. comm., Nov. 1985).

[2] Where Ca, Mg, and Cl are higher, extra NH_4 fertilizer may be beneficial.

[3] SAR = sodium adsorption ratio = $Na / \sqrt{(Ca + Mg)/2}$.

[4] ASAR = adjusted SAR = SAR $[1 + (8.4 - pH_C)]$, where pH_C is the theoretical pH of water in contact with lime at atmospheric levels of carbon dioxide.

[5] RSC = residual sodium carbonate = $(CO_3 + HCO_3) - (Ca + Mg)$.

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CHAPTER 2

SITE PREPARATION

Proper site preparation on all orchard sites facilitates subsequent management operations such as layout of planting spots, planting, fertilizer and chemical applications, and cone collection. Site preparation differs for seedling and clonal orchards both in methods and intensity. APPENDIX III includes a table for summarizing and recording the various operations.

Soil Drainage

If a hardpan is found during initial site assessment, the type of problem, if any, that it creates must be determined. A hardpan at a depth greater than 1 m will do little to limit rooting directly but may affect it indirectly through impeding water drainage. Hardpans at depths greater than 1 m will, for all practical purposes, be too deep to be broken up. The options for correcting water drainage problems are as follows.

1. Avoid them.
   Ensure that there is sufficient extra area to meet requirements and that these abnormal areas do not affect the remaining area, e.g., wet areas may break up the orchard creating problems in operation.
2. Rectify them.
   a. By deep subsoiling (break up hardpans).
   b. By installing ditches or drainage tile (remove excess water).
   c. A combination of a and b.

Subsoiling to a depth of 50-100 cm, using a large bulldozer equipped with a ripping claw, breaks up the hard pan. A grid pattern at 3-4 m spacing will provide good coverage of an area. Drainage tile may be necessary if there are large depressions on the site. A subsurface drainage plow using a laser grade control system can be used to install plastic drainage tubing. A large blade, with a hollow chute into which the tubing is fitted, is pulled through the soil. As the plow moves, the tubing is drawn through the chute into the soil at the bottom of the blade. The laser establishes a pre-determined sloping reference plane over the site allowing drains to be installed with great accuracy. The Atlantic Committee on Agricultural Engineering publication titled "Farm Drainage in the Atlantic Provinces" (Gartley *et al.* 1986) provides valuable information on soil drainage systems. Contact a Department of Agriculture drainage engineer for advice on the appropriate method(s) to solve soil drainage problems.

Forested Sites

Seedling seed orchards

Site preparation for seedling seed orchards should not change the environment appreciably from that of a normal planting site because the trees are evaluated for differences between families (when rogueing) and for the production of seed. Seedling seed orchards are best established on cutover forest land. Preparation should aim at improving the uniformity and operability of the site. A major objective of any type of scarification is to mix the organic matter layer with the mineral soil and not expose mineral soil or strip off the organic matter layer. Slash should not be piled and burned on the site, except where roads are planned, because burning alters soil nutrition regimes.

During the cutting operation, stumps should be cut as low as possible. The slash can be removed from the site using a brush rake such as an Eden rake or Raumfix rake. An experienced equipment operator is required because the soil should be left intact. If slash is not removed then double crushing or a double pass with Drum choppers or a Rome Disc will break up and flatten it. The Madge Rotoclear, which acts like a rototiller, chews stumps and slash and mixes them with the mineral soil to create a garden-like site. Stumps must be no higher than 12 cm above the ground and be at least 6-12 months old.

Competing vegetation must be controlled before it affects the growth of the orchard seedlings. The most effective and cost efficient time to begin weed control, is BEFORE planting. However, because unwanted vegetation does not usually grow until after harvesting, such treatments may not be applied until the seedlings have been planted (see CHAPTER 4 for herbicide treatment).

Clonal seed orchards

The sole purpose of clonal orchards is to produce abundant quantities of seed. Therefore everything possible should be done to favor early and abundant cone production.

Slash and stumps should be removed from the site using a root rake. As much soil as possible should be shaken from the roots before they are removed. Slash and stumps should not be burned on the site, except where roads are planned, because of the effect of burning on soil nutrition. Large boulders can also be removed from the site at this time.

The site should now be harrowed to smooth the surface and raked to collect surface rocks and pieces of roots and slash in windrows where they can be removed with a rock picker. Following this operation, large depressions can be filled and mounds removed to produce a flat surface. Plowing the soil to a depth of 25 to 30 cm will mix in the organic matter layer and when harrowed will further loosen the soil and make it more manageable. Rock picking may again be necessary.

Fertilizer and/or lime amendments should be applied at this time, based on the results of soil sample analyses (see CHAPTER 5, Assessing Site Fertility). Harrowing will help to incorporate the amendments into the soil and prepare the site for sowing the cover crop.

Field Sites

Seedling and clonal seed orchards

When a field site is selected for a seed orchard, the site preparation procedures will be similar for both types of orchards, but less intensive for seedling orchards. Seedling orchards are not usually established on fields because such locations are not typical planting sites for reforestation programs. However, occasionally field sites are used because preparation costs may be lower and initial management may be more economical.

Before operations begin, the site should be assessed to determine if land forming is necessary. If required, it should be completed before plowing and harrowing. If a hardpan, exists, it must be broken up by methods discussed earlier. If there is vegetation growing on the field, the entire area should receive an application of herbicide in late spring or early summer (see CHAPTER 4 for herbicide application). About one week following the herbicide application the site may be plowed and harrowed. Fertilizer and lime amendments, as recommended from results of a soil analysis, should be applied and harrowed into the soil. This operation may not be necessary if the site is to be used for a seedling orchard unless certain nutrients are limited. If during the summer fallow period, weeds and grass reestablish on the site, a second herbicide application followed by harrowing may be necessary. This should be done at least one to two weeks before the cover crop is sown. Frequent harrowing during the summer months may be sufficient to control regrowth of weeds and grasses.

Cover Crops

An essential part of a clonal seed orchard is a permanent grass cover crop. Clare *et al.* (1984) provide guidelines for the establishment and management of the permanent cover crop.

Cover crop characteristics

A seed orchard cover crop should be long lived, and produce a thick sod that is able to prevent erosion and withstand traffic. If should also exhibit short growth (infrequent mowing), low fire hazard (thatch remains green), contain no clover (rodent control), and be aesthetically pleasing.

Fertility requirements for seeding

Growing and maintaining a grass sod requires regular fertilizing with N, P, and K. Some soils require additional Ca and Mg as determined by soil analyses. Fertility levels of the orchard site MUST be determined BEFORE seeding the cover crop (Table 2-1).

Lime is usually required in the year of establishment. Lime and fertilizer should be mixed into the soil to a depth of 8-12 cm before seeding. No benefit comes from deep incorporation as most grass roots are shallow.

Fertilizer and lime can be spread by broadcast or band type (Gandy) spreaders. The band type is recommended as the fertilizer can be applied more accurately to the grass and not on the trees.

Table 2-1. Soil fertility levels (top 10 cm) for establishing a grass cover crop

	pH	Organic matter (%)	P_2O_5 (kg/ha)	K_2O (kg/ha)	Ca (kg/ha)	Mg (kg/ha)
Recommended	5.5-6.0	4.0-5.0	150	150	300-400	200-300
Minimum[1]	5.0	2.0	100	100	250	150

[1] At or below minimum values, grass will be less vigorous and may die in stressed areas.

Seeding

Best results are obtained from spring or late summer seeding (Table 2-2). Summer or fall seeding should be avoided. A spring seeded cover crop with a 50:50 mixture of common Kentucky Bluegrass:common Creeping Red Fescue produces a good sod that will withstand light traffic after August 1.

Table 2-2. Date and rate of seeding for a seed orchard cover crop

Date	Seeding rate (kg/ha)
May 15 - 31	45
June 1 - 15	60
June 15 - August 15	Do not seed
August 15 - September 15	45
After September 15	Do not seed

Seed should be placed in the top 1 cm of soil. GRASS SEED SOWN DEEPER THAN THIS WILL NOT GERMINATE. After the seedbed is prepared, seed can be applied with a cultipacker-type seeder (Brillion), or a regular seed drill with a forage seed box, or broadcast with the fertilizer. To ensure good coverage of the site, seed at half the recommended rate, and repeat at right angles to the first seeding (checkerboard pattern).

In the year of seeding, the sod will not be well established and could be damaged by heavy or frequent traffic. This problem will be more severe if soil fertility is low and plants are weak.

Maintaining fertility levels

It can take up to 5 years for a sod to become fully established. Consequently, fertilizer may be required each spring and summer (Table 2-3). After year 5, the type and rate of fertilizer applied for the cover crop should be based on the condition of the sod and the amount of traffic expected in the upcoming year. Apply 2 t/ha lime every 5 years or as indicated by soil tests.

The spring fertilizer should be applied in mid-May. NOTE: Never apply fertilizer to frozen soil. The spring nitrogen application should be with nitrate fertilizers because the nitrogen is immediately available in cold soils. In summer, fertilizer should be applied in late June or early July. Avoid fertilizing trees when fertilizing the cover crop, especially in late summer. Fertilizing after mid-July increases the danger of inducing lammas growth on trees, making them susceptible to fall frost damage. The larches, *Larix* spp., are extremely susceptible to this damage.

Table 2-3. Fertilizer amendments for maintaining healthy sod

Time	Fertilizer	Rate (kg/ha)
Years 2-5		
Spring	15-15-15	200-400
Summer[1]	15-15-15	200-400
After year 5, sod in good shape		
Spring	34-0-0	50-70
Summer[1]	34-0-0	50-70
After year 5, sod in poor shape, years of heavy traffic, or low P & K		
Spring	15-15-15	200-400
Summer[1]	15-15-15	200-400

[1] Summer means late June to early July, not after mid-July. Always do a soil test and use this table only as a guide.

Maintenance mowing

Two to four mowings during the summer should control growth of the cover crop. To control rodents, mowing should be done in the fall after growth stops. Use a tractor-drawn rotary mower or flail mower to mulch the growth. Cut at a height of 5-10 cm. An agricultural reciprocating mower leaves a swath of grass which will create a fire and rodent hazard.

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CHAPTER 3

ESTABLISHMENT

This phase of seed orchard development involves selecting a design, spacing, and layout that are easy to implement, best satisfy genetic considerations for seed production, and provide ease of orchard tending. Extreme care and attention to detail are 'musts' during the planting and mapping stages to ensure good survival and to prevent errors. Tending and maintenance following planting are important to promote quick establishment and early, rapid tree growth. APPENDIX IV, Table IV-1 is a form for recording various operations on an annual basis.

Design and Spacing

The major objective of a seed orchard design is to maximize out-crossing and panmixis (random pollination) while minimizing self-pollination and related mating. It is also important to provide for future expansion and rogueing. Spacing of the orchard trees should take into consideration planned rogueing intensity and easy movement of equipment.

Seedling seed orchards

Design

A design incorporating planting a large number of families with many seedlings of each family at close spacing is recommended for seedling seed orchards. The close spacing allows for two to three rogueings with a final rogueing intensity of 85 to 90%. The intensity of each rogueing depends on the need to maintain a full, open crown on the remaining trees, maximize genetic gain, and assure easy movement of equipment.

The general design that is being used for seedling orchards in the Maritimes is the single-tree plot. In this design one or more seedlings from each family are randomly planted in each row or block of the orchard.

Using the row design, the number of rows is determined by the average number of seedlings available per family. A minimum of 100-150 families with 100 seedlings per family should be planted at any one time (minimum area of 3-4 ha, if no additional area is to be planted). Numbers of this magnitude allow for reasonable selection intensities during rogueing and the production of outcrossed seed. When laying out the orchard, a 5-m-wide strip should be left unplanted at every 15th row for access roads. Stakes are placed at the beginning and end of each row and at every 50th planting position within rows. These subdivide the rows into subsets providing tie-in points (Fig. 3-1A).

When using the block design, blocks must be sufficiently large (50 X 50 m) because area is required for access roads. Seven to nine seedlings per family should be planted in each block depending on spacing. A minimum of 150 families is necessary to ensure a sufficient number of unrelated trees remain after final rogueing. To ensure that ample area is planted at any one time, 12-15 blocks are recommended (3-4 ha). A 5-m-wide access road is left around each block but no provision is made for vehicle access within the blocks. Both ends of the rows are staked (Fig. 3-1B).

Spacing

Spacing must be close enough to allow for planting many seedlings per unit area but not so close that competition for growing space forces too early and intensive rogueing. Conversely, if too wide a spacing is used, the orchard cannot be rogued as heavily as may be required to maximize genetic gain or too few trees may be left, thus reducing seed production per unit area.

The 2 x 1-m spacing generally used in the Maritimes, appears to be adequate for black spruce, but for jack pine which grows faster and produces a larger crown, 1.25 x 2.50 m may be more appropriate.

Clonal seed orchards

Design

For clonal orchards, a more sophisticated design is necessary because fewer unrelated individuals are planted and rogueing is at a lower intensity than in seedling seed orchards. Forty to 50 clones are sufficient for a clonal orchard or in separate blocks if the site is large (greater than 4 ha). This number will be reduced by 50% by rogueing and miscellaneous losses.

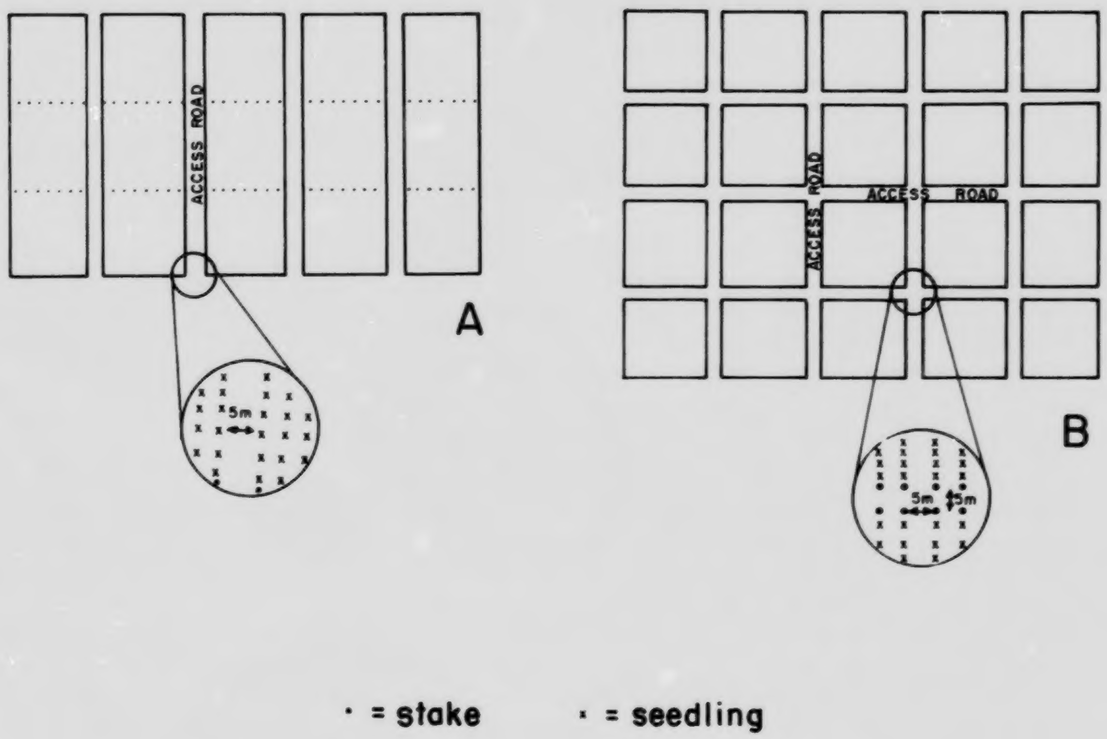
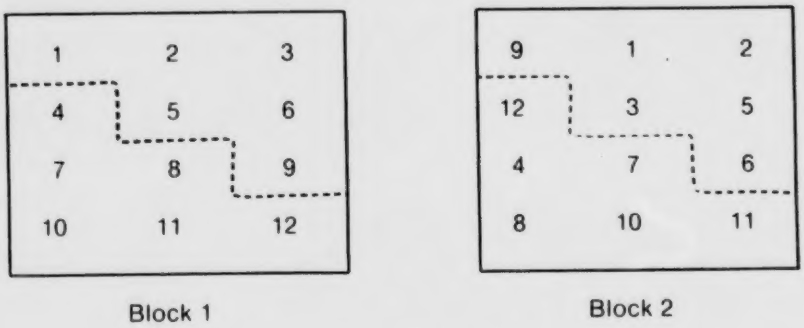


Figure 3-1. Seedling seed orchard designs: A- row, B- block.

Clonal orchards will be rogued primarily on the basis of results from control pollinated progeny tests. Clones that do not produce large numbers of cones will be culled.

Many designs have been proposed for clonal seed orchards. The ramets can be planted either systematically or randomly. When an orchard layout is designed systematically the ramets are placed in a predetermined pattern (Fig. 3-2). Although such designs maximize outcrossing, panmixis is much reduced and the spacing after rogueing may be unacceptable.

Using the random orchard design, each ramet of each clone has an equal opportunity to be selected for any given planting position. The one major restriction imposed is that at least two different ramets must separate those of the same clone. This design may be implemented by completely randomizing all the available ramets of all clones among all available planting positions, or by dividing the area into blocks each sufficient in size to contain one ramet of each clone or a multiple so there are an equal number of ramets per clone.



1	2	3	4	5	6	7	8	9
4	5	6	7	8	9	1	2	3
7	8	9	1	2	3	4	5	6
1	2	3	4	5	6	7	8	9

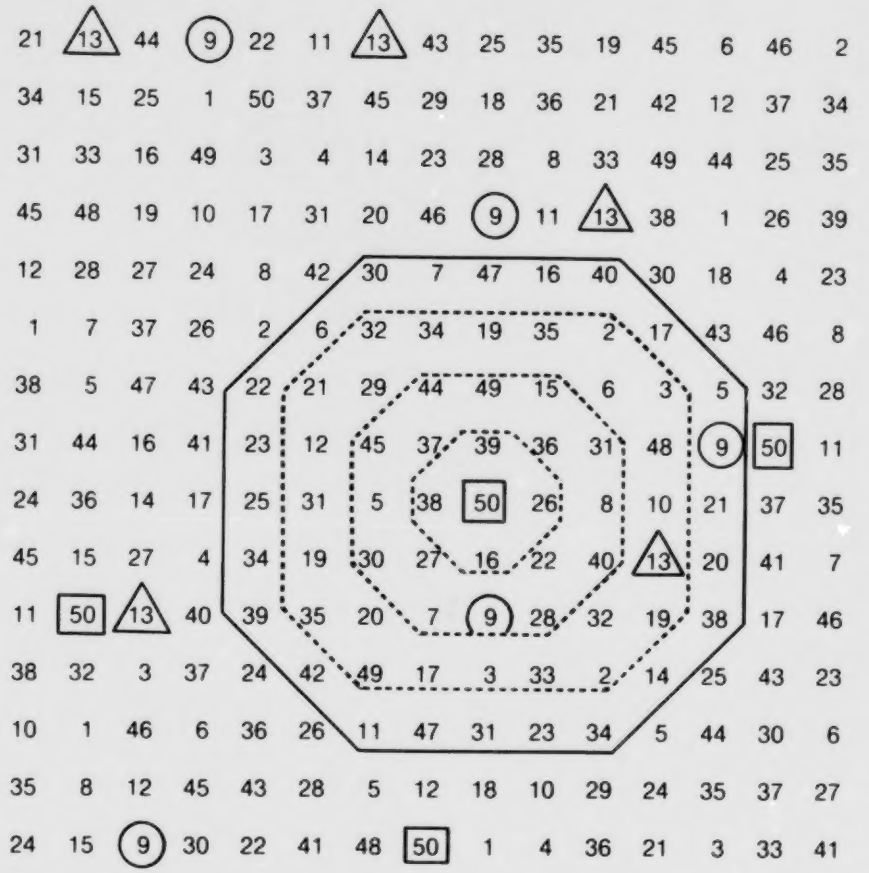
Figure 3-2. Two systematic clonal seed orchard designs.

A computer program called COOL (computer organized orchard layouts), developed by Bell and Fletcher (1978) to produce random layouts, is being used in the Maritimes by the Canadian Forestry Service - Maritimes, Fredericton; P.E.I. Department of Energy and Forestry, Charlottetown; and N.S. Department of Lands and Forests, Debert. The design is based on the permutated neighborhood concept and randomized with two restrictions: proximity of two ramets of the same clone and repetition of the direction of two adjacent clones. To run the program, the following information is necessary.

1. The dimensions of the orchard as defined by a specified number of rows and columns.
2. The number of ramets per clone.
3. Design type that specifies the number of planting positions in any direction by which a clone is isolated and within which no other ramet of the same clone can appear.
4. The number of times two clones can occur in the same immediate position relative to each other.

Figure 3-3 illustrates a portion of an orchard designed by this program. The diagram shows that when a design type of 5 is chosen, a ramet of clone 50 is separated from all other ramets of that same clone by at least four rings of different clones. A design type of 5 should be considered as a minimum when this program is operated to maximize distances between ramets of the same clone.

Three layout patterns may be used: rectangular, square, or triangular (Fig. 3-4). The triangular pattern allows more efficient use of growing space for the tree crowns than does the square. The rows in the rectangular design should be oriented east-west to allow the crowns maximum light exposure on the south side.



21	13	44	9	22	11	13	43	25	35	19	45	6	46	2
34	15	25	1	50	37	45	29	18	36	21	42	12	37	34
31	33	16	49	3	4	14	23	28	8	33	49	44	25	35
45	48	19	10	17	31	20	46	9	11	13	38	1	26	39
12	28	27	24	8	42	30	7	47	16	40	30	18	4	23
1	7	37	26	2	6	32	34	19	35	2	17	43	46	8
38	5	47	43	22	21	29	44	49	15	6	3	5	32	28
31	44	16	41	23	12	45	37	39	36	31	48	9	50	11
24	36	14	17	25	31	5	38	50	26	8	10	21	37	35
45	15	27	4	34	19	30	27	16	22	40	13	20	41	7
11	50	13	40	39	35	20	7	9	28	32	19	38	17	46
38	32	3	37	24	42	49	17	3	33	2	14	25	43	23
10	1	46	6	36	26	11	47	31	23	34	5	44	30	6
35	8	12	45	43	28	5	12	18	10	29	24	35	37	27
24	15	9	30	22	41	48	50	1	4	36	21	3	33	41

Figure 3-3. Portion of a computer generated clonal seed orchard design (COOL) using 50 clones and design type 5.

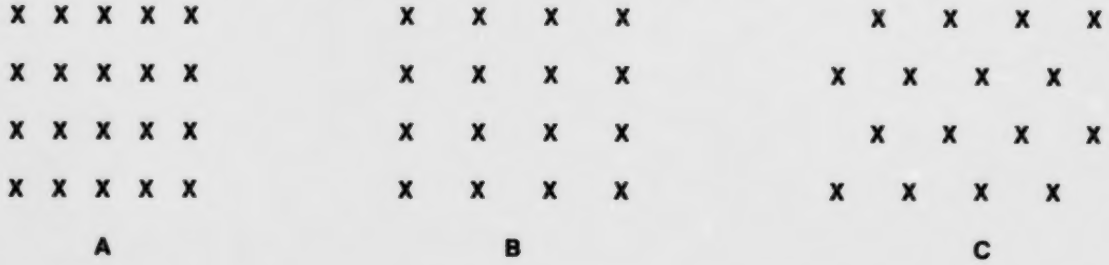


Figure 3-4. Layout patterns for clonal seed orchards: A - rectangular, B - square, C - triangular.

Spacing

Spacing in clonal seed orchards is wider than that in seedling orchards because only about 50% of the trees will be rogued, and to allow easy movement of equipment. However, such orchards are not usually rogued until they are 15 to 20 years old. Therefore, spacing must also take into consideration that crowns require full exposure to light and that following rogueing, the amount of open, unproductive area be minimal. A spacing of 3 x 6 m should be sufficient for the rectangular pattern, while 4.5 x 4.5 m is adequate for the square and triangular layouts.

Layout, Planting and Tending

After selecting an orchard design and spacing, it is necessary to measure and stake rows, blocks and/or tree planting positions as dictated by the design. All seedlings or grafts must be clearly labelled before they are taken to the site. Planting a seed orchard requires more time, care, patience, supervision, and planning than does a production plantation because each tree and its location must be identified and mapped and survival standards are higher. Tending and maintenance is necessary to promote quick establishment and early, rapid growth of the trees.

Seedling seed orchards

A transit is the best instrument to use for accurately placing corner stakes and aligning rows and blocks. However a hand held penta-prism is cheaper, quicker, and almost as accurate. Wooden stakes treated with preservative are sufficient but permanent stakes such as aluminum or steel angle or concrete reinforcement rods are also suitable. When all rows and blocks have been established, the individual planting spots are marked with plastic pot markers. This ensures uniform spacing. If the individual planting spots are not marked before planting, the seedlings can be planted at the appropriate spacing within rows using a line with the spacing marked on it. The line is stretched to include four to six rows with one planter per row and is moved up the rows one planting space at a time. Care must be taken to keep the line straight and not skip a row at one end.

Black polyethylene strips (1.25 to 6 mil) can be laid in rows over tilled soil before planting. This has been used with some success in a black spruce seedling orchard and effectively controlled weeds except where weeds grew through the planting holes in the plastic. The seedlings do not suffer adverse effects from heat or lack of moisture. Thin polyethylene does not withstand the first winter as well as the higher grade.

Seedlings are usually greenhouse-grown and as such are planted at age five to six months, or overwintered and planted the following spring. Randomization of the seedlings is greatly facilitated when they are grown in containers such as Japanese paper pots, Can-Am's or Ray Leach tubes, one family per container or tray. Before planting, each seedling must be labelled with a paper adhesive label on which the family number is inscribed. Seedling identities must be maintained until they are mapped in the orchard. Such labels are easily produced using a printer and computer.

Seedlings must be planted at or as close to the designated planting spots as possible. No seedling should be offset by more than 15 cm and if so should only be offset up or down the row, NEVER to either side. The orchard should be mapped at the time of planting to ensure proper identification of the seedlings before the numbers on the labels become illegible or the labels become detached. The maps should be double checked to avoid errors.

Close attention should be paid to tree survival and competition from unwanted vegetation. If survival is less than 90% after the first year, dead seedlings should be replaced with members of the SAME family only. Applying mulch or fertilizer to each tree is not necessary except when the organic matter layer and top soil have been removed (see last paragraph, next section).

Clonal seed orchards

When the layout and spacing have been determined, the next step is to transfer the plan from paper to the orchard site. Again, a transit is an invaluable piece of equipment for this work. All planting positions should be staked. Using the design map, a permanent metal tag containing the clone number should be attached to each stake. Other information, such as row number, position within row, block number, year grafted, etc., may also be inscribed on the tag. Large wooden stakes reduce the aesthetics of such orchards, especially when the grafts are small. Short metal stakes or heavy guage wire to which the tags are attached can be used.

Herbicide can be applied to an area, up to 1 X 1 m, around each planting position or a strip down the rows before planting the grafts. If the herbicide is applied after the grafts have been planted and they are actively growing, extreme care must be taken to prevent the herbicide from contacting the trees (see CHAPTER 4 for suitable herbicides).

Only vigorous grafts with healthy shoots and buds should be planted in the orchard. Grafts from winter greenhouse grafting may either be transplanted to the nursery in the late spring or early summer or retained in pots until they are large enough to be planted in the seed orchard. Current-year grafts that have grown well can be transplanted to the seed orchard the same year. Square pots, 4.5 L, with root-trainer ridges on the inside walls are suitable for growing grafted material for 1 to 3 years with a minimum of root deformation. Such material should be overwintered in an unheated, shaded, sealed greenhouse to avoid damage. Potted grafts are easier to transport to the seed orchard for planting than nursery transplants, and may be planted one year sooner because planting shock is minimal and root loss and deformation are eliminated or reduced. The current trend in the Maritimes is away from transplanting grafts to the nursery bed and subsequently to the seed orchard, to planting current-year grafts into the orchard and overwintering the remaining grafts for orchard planting the following spring.

Grafts should be lifted from the nursery before the buds flush. This must be coordinated with the phenology of the species. Tamarack, for example, should be dug as soon as the ground thaws, whereas red or black spruce can be left in the ground longer. Before lifting, each graft should be tagged with plastic nursery tags or permanent metal tags recording the clone number. When lifting, as much soil as practical should be left on the rootball. The roots and shoots can be pruned as required for handling. The size and fragility of grafts dictate careful handling - KEEP THEM IN AN UPRIGHT POSITION. Large plastic or metal containers labelled with the row and planting location can be used. The roots must be protected and kept moist by covering them with wet peat moss. Grafts may also be individually placed in buckets or plastic bags.

A large auger or posthole digger mounted on a farm tractor is a good combination for digging holes but care must be taken to reduce compaction of the sides of the holes. If this happens, the sides should be loosened by making vertical cuts with a shovel before the grafts are planted. NOTE: Do not bore holes when the soil is wet.

Careful outplanting minimizes losses and planting shock. The roots must be spread out in an adequate sized hole and planted at the same depth as they were previously growing in the nursery or pot. For grafts in pots with roots fully occupying the potting medium, make several vertical cuts through the roots with a sharp knife to help promote lateral root growth.

It is often necessary to have the grafts staked to prevent snow and ice damage during the first two or three winters in the orchard. This also encourages some grafts to grow upward to form a tree rather than to grow in a branch-like fashion (topophysis). All grafts not having a topophytic growth habit should be untied during the summer months. This encourages the development of a more sturdy tree.

Grafts must be carefully pruned for two or three years to remove all the branches from the root stock, leaving only the grafted scion. Pruning should be initiated at the greenhouse/nursery but completed in the orchard. Pruning is best done in the spring before the buds have flushed and can be repeated in early August. Large branches should be removed first. If large branches are left for several years, the size of the wound following pruning increases stress on the graft. If all large branches cannot be removed at one time, those remaining may be pruned back. When removing whorl branches, never remove more than two at one time and remove ones opposite each other. Removing most or all the whorl branches at one time creates too much wound area thus promoting tissue desiccation and eventually girdling. Branches should be pruned flush to the branch collar (Fig. 3-5). Damaging this collar by

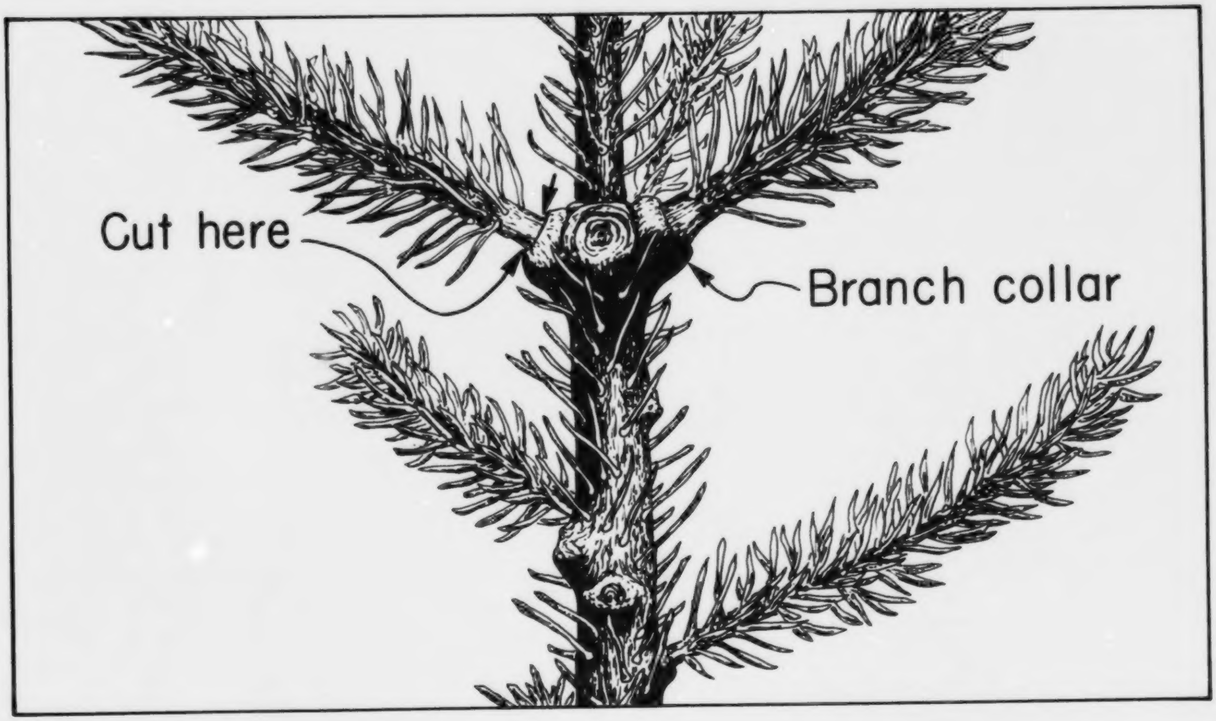


Figure 3-5. Proper pruning method on conifer grafts.

pruning too close retards the tree's natural wound healing processes and allows the entry of microorganisms (Shigo 1985). Treatment of pruning wounds is not necessary. Grafts growing vigorously can be pruned more heavily than slow growing ones. Keep the scion dominant at all times. NOTE: Use discretion when performing this task.

Following planting, a mulch layer of peat moss or sawdust around each graft increases survival and early growth. Mulch provides a layer of insulation moderating soil temperatures at ground level and helps retain soil moisture and nutrients while reducing competing vegetation. Well decomposed sawdust should be used as it does not immobilize soil nitrogen to the same extent as fresh sawdust. Ground-up cones should be avoided because there inevitably will be some viable seed present and the cones will also immobilize nitrogen from the soil as they decompose. The mulch should be applied in a 40- to 60-cm-diameter circle 5-cm-thick, around the grafts but should not be in contact with the stem. Too thick a layer may encourage nesting or burrowing by mice or other rodents or attract insects.

DO NOT apply granular fertilizers until a month after transplanting the grafts in the orchard. Fertilizer is not usually required the first season following planting as there should be ample nutrition in the potting medium or soil within which the roots have grown. However, if fertilizer is to be applied the same year as transplanting, it should be placed around the outer edge of the planting hole before the mulch is spread. Ammonium nitrate and 10-10-10 in a 2:1 mix by volume at the rate of 30 g per graft is sufficient and will not harm the roots if applied carefully.

Field Grafting

Field grafting may produce a healthy, fast growing tree and result in early cone production as it eliminates transplanting the grafts to the orchard. It also extends the grafting season. The major disadvantages are that grafting must be done outdoors often under difficult conditions, success is usually lower than with greenhouse grafting, and growth is poorer the first two to three years.

This technique, although not used extensively in the past, shows promise for use in the Maritimes. Complete sections/blocks of an orchard should be established at one time. Combining field and greenhouse grafts often complicates early tending and management. The root stock, two seedlings per planting position, is established one to two years prior to grafting. The grafting may be conducted during mid- to late spring (May). NOTE: Be careful not to leave any ungrafted rootstock.

For spring grafting, use dormant scions collected in March and stored frozen in snow. The scions are grafted using the side-veneer grafting technique (see Hallett *et al.* 1981). Protection from desiccation is not necessary.

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CHAPTER 4

VEGETATION MANAGEMENT

Orchards can be divided into two broad categories for the purpose of vegetation management; those with and those without a grass cover crop. The former includes orchards established in fields, and where a cover crop was sown. The management system differs for each orchard, but in general, for orchards established on formerly wooded sites without a cover crop, a combination of manual cleaning and herbicide application is effective. For seedling seed orchards established in fields and clonal orchards with grass cover crops, grass can be controlled by mowing and herbicides (see APPENDIX IV).

Regardless of the type of orchard, unwanted competition should be killed or its growth retarded so that orchard tree growth is not hindered. Control of competition in seed orchards involves two aspects.

1. Localized control - ensure that trees are not subject to direct competition for light, water, nutrients, etc. Grass competition can significantly reduce early height growth of conifer seedlings (Sims and Mueller-Dombois 1968).
2. General control - regulate aesthetics and accessibility within the orchard.

Localized Control

In orchards with sod cover, it is often desirable to use a herbicide or mulch to kill a patch of grass immediately surrounding the trees. This facilitates mowing, because the crowns of young trees do not produce sufficient shade to control the grass around them (see CHAPTER 3, for details on mulching around trees). Applying herbicide to kill grass around trees eliminates hand-mowing. The size of this patch is determined by efficiency of mowing, e.g., minimize the number of passes between rows. Killing a strip of grass along the rows eliminates mowing across the rows.

General Control

In orchards with sod cover, mowing is the most common method to control vegetation. For orchards without a sod cover, manual cleaning, alone or in combination with herbicide application(s) is required.

Herbicides

AT THIS TIME, THERE ARE NO HERBICIDES SPECIFICALLY REGISTERED FOR USE IN SEED ORCHARDS IN THE MARITIMES. However, there are several herbicides registered for forestry use in Canada. The following sections include a general discussion on the use of herbicides in seed orchards followed by a brief description of some herbicides with potential use.

For seed orchards, as with any plantation, the steps to follow BEFORE using any herbicides are.

1. Determine the need to control the competition.
2. Is the use of herbicides justified or would spot-cleaning with saws or axes be cheaper, as effective and long-lasting?
3. If herbicides are deemed necessary, identify the target weed species and MATCH the registered herbicide with the target.
4. Select the proper time and rates of application (read the instructions on the label). "The registered herbicide label is the final authority and source of information on how a herbicide may be used safely and properly" (B.C. Min. Environ. 1986).
5. Obtain spray permits.
6. FOLLOW ALL SAFETY PRECAUTIONS IN THE HERBICIDE/CHEMICAL HANDBOOK (Ont. Min. Agric. Food 1986). **APPLICATORS MUST BE PROPERLY TRAINED.**

Conifer seedlings are especially susceptible to herbicide injury the year of planting. Therefore, herbicides should not be used adjacent to the trees the same year as planting. If herbicides such as simazine and velpar, which have considerable soil residue activity have been used, wait at least one year before planting. When post-planting brush control is required, several herbicides are suitable for use the year after planting. The choice of herbicide and application method and rate depends on the target species, the severity of competition and the tree species. For detailed information on herbicide use consult the annual "Guide to Chemical Weed Control" (Ont. Min. Agric. Food 1986) distributed in the Atlantic region by authority of the Atlantic Ministers of Agriculture.

There are numerous types of herbicide applicators, which can be used to apply herbicide around trees, minimizing the risk of herbicide accidentally contacting foliage. Sprayers equipped with "shrouds" can be used when the seedlings are young to protect them against the spray. For larger trees, a field sprayer can be modified with a shroud to direct the spray to the ground and under the lower branches. Wick-type applicators can also be safely used but are time consuming. Descriptions of the equipment available and their calibration can be found a handbook published by the B.C. Min. Environ. (1986).

Several of the chemicals that potentially could be useful for vegetation control in seed orchards are briefly described below.

Vision (glyphosate)

Vision (formerly called Roundup) was registered in 1984 for forestry use. It is effective against many species of weeds and hardwoods, is of low toxicity to wildlife, fish, and humans, and is quickly inactivated and degraded in soil. Woody species are most sensitive in August or September before frost (Kersting *et al.* 1983). During the growing season, Roundup can be used as a knockdown herbicide, but it must be applied around the tree seedlings as a directed spray and not applied on the crop trees.

Princep Nine-T (simazine)

Simazine inhibits seed germination. Therefore, it must be applied either when the ground is free of weeds or in combination with another herbicide such as Vision which provides the knockdown. Simazine is best applied when trees are dormant as it has considerable soil residue activity. Larch and container stock are especially sensitive to damage by simazine while spruces are more sensitive than pines and fir. Conservative rates should be used for the more sensitive tree species and stock types. At low application rates, grass control may not be complete. Because of its residual activity, annual applications may not be necessary. Soils should be tested for toxic buildups of simazine if repeated applications have been used (see CHAPTER 1, Past land use).

DCPA Dacthal 75W (chlorthal dimethyl)

Dacthal is effective in controlling annual grasses and some broadleaf weeds but is not as effective for perennial weeds or grasses (Kersting *et al.* 1983). It is a mainstay in many nurseries for control of weeds in seedbeds. Like other preemergence herbicides it must be applied early in spring before weed seed germination or growth commences. A major advantage of DCPA is that there are generally no phytotoxicity problems with most of our native conifers (Hallett and Burns 1984).

Kerb 50 W (pronamide)

If the buildup of simazine residues or its toxicity is of concern then Kerb is an alternative. Kerb, applied to the soil as a spray in the fall, controls many overwintering annuals and perennials. It is applied only on cold soil because at warm soil temperatures, it readily volatilizes. By summer of the year following application, most of the Kerb will have dissipated. Kerb is absorbed through the roots, thus to be effective, moisture from rain, irrigation, or snowmelt is essential to move it into the rooting zone.

Velpar L

Velpar L was registered in 1984 for woodland use. It is effective against grasses, broadleafed weeds, and woody perennials. At low application rates, black and white spruces and jack pine may be planted immediately after application, but ALL OTHER conifer species should not be planted until the following year regardless of the application rate used (Teskey and Boyer 1984).

Combined sprays

Some herbicides can be combined to achieve a broad spectrum of control for a long period. For example, Vision and Princep can be combined, the former being used as a knockdown spray while the latter provides residual weed control. Princep can be combined with Dacthal to provide a broad spectrum control of grasses and broadleaved weeds throughout the growing season (Hallett and Burns 1983).

Suggested Readings

British Columbia Ministry of Environment. 1986. Handbook for pesticide applicators and pesticide dispensers. A.V. Miller and S.M. Craig [Eds.] Pesticide Control Branch, B.C. Min. Environ. 233 p.

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CHAPTER 5

FERTILITY MANAGEMENT

Soil fertility will affect the quantity and quality of seed produced in the orchard. The control of orchard fertility can be regarded as a two-stage process: assessment and maintenance. The assessment stage involves determining the fertility status of the site and alleviating any deficiencies. The management stage involves maintaining nutrients at optimal levels for both tree growth and cone production. Annual fertility management operations should be recorded (APPENDIX IV).

Assessing Site Fertility

Soil sampling

Soils in an orchard must be systematically sampled. Soil pits should be dug and bulk soil samples collected for nutrient assessment.

It is not practicable to try to manage a seed orchard on an individual-tree basis, nor should a 100 ha orchard be managed as one entity. Therefore, workable management blocks, that can be treated as homogeneous units must be identified. To do this, blocks/areas are identified which can be managed separately. The management blocks are usually determined by some logical subdivision of the orchard such as species, suborchards, or year of establishment within a given species (Fig. 5-1).

In the hypothetical seed orchard (Fig. 5-1), four management units are delineated by roads. Information on the type(s) of soil is obtained from soil pits (P) and fertility samples (*). Before establishing the orchard, this information is used to identify differences in soil types both between and within the management units.

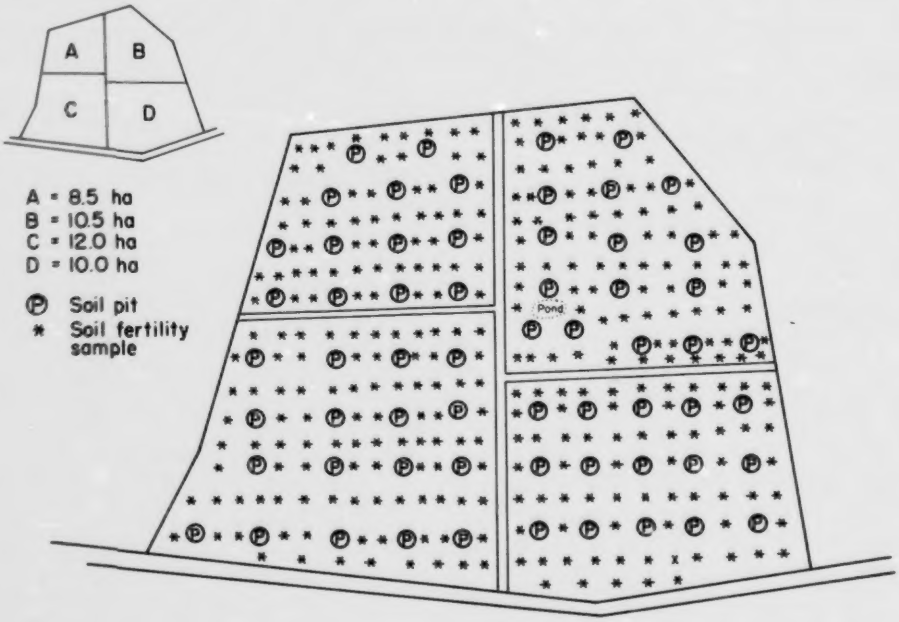

Figure 5-1. A hypothetical seed orchard with its permanent road system used to subdivide the orchard for soil sampling.

Soil pits are systematically located to represent soils from the entire orchard area. The number of soil pits required increases with increasing variation on the site. Soil types often change with slope position, distance from a body of water (old river-bank terraces), etc. The three pits located around the pond in Fig. 5-1 are necessary to determine how far the influence of the low wet area extends. The boundaries of any other abnormal areas should be similarly delineated, e.g., hardpans. NOTE: This assessment is done BEFORE orchard trees are planted (see CHAPTER 2, Soil drainage).

Sampling to determine variation in a single orchard block should be done in one year. DO NOT collect a small number of samples and if the variation is high, collect more samples the following year. If samples are collected in year 1, and subsequently the site is disturbed, e.g., plowed and harrowed, nutrient levels of soil samples collected immediately after the disturbance may be significantly higher than before the disturbance. This nutrient flush is temporary, but still inflates the nutrient levels in the second samples.

After the variation in soil types has been determined, soil fertility samples should be collected. The variation in the soil types in each sampling area, as determined by the soil pits, should be used to determine the minimum number of samples required. NOTE: Chemical analyses of the upper horizon(s), the top 15 to 20 cm, from the soil pit samples can also be used to supplement the cores.

It is important to collect samples distributed throughout the sampling area. The following procedure is designed to ensure that the entire area is sampled and that sufficient sample is collected. The major costs arise from processing and analyzing the samples, NOT from collecting them. DO NOT CUT CORNERS WHEN COLLECTING SOIL SAMPLES.

1. *Previously unsampled sites, sites with known high variability e.g., seedling seed orchards on cutovers:* A minimum of 10 to 15 cores per hectare should be collected. Sampling in a grid pattern at a 25 X 25 m spacing equals 16 samples per hectare.

   Previously sampled sites, and existing orchards with the top 15 to 20 cm plowed and mixed to create a homogeneous plow layer e.g., clonal orchards: A minimum of 5 to 10 cores per hectare should be collected. Sampling at 40 m X 40 m equals 6 samples per hectare.
2. Using a soil auger, take cores to a depth of 15 to 20 cm. Small diameter augers, e.g., 2 cm, or larger sizes can be used. THE SAME NUMBER OF SAMPLES SHOULD BE COLLECTED REGARDLESS OF THE SIZE OF THE AUGER.
3. Mix all the samples from each sampling area, removing large roots, clumps of sod, etc.. Use a CLEAN "ship n'shore" container in which to mix the soil. DO NOT use old oil barrels or similar containers that might contain residues which could contaminate the soil.
4. If a large diameter (10 cm) sampling auger is used the total amount of soil collected will be much more than is needed for analysis. Mix the soil thoroughly and take a 1-L subsample randomly from the total soil sample.
5. Place each sample separately in a heavy paper bag (sugar bags are ideal). Label the bags with waterproof ink, and map the exact locations in the orchard where they were collected. If the blocks have not yet been planted and no permanent reference points are available, the samples must be plotted as closely as possible on maps.
6. Air-dry the samples and store them in a cool, dry, environment until they are shipped to a laboratory for analysis. DO NOT store soil samples in plastic bags.

Sampling for annual fertility assessment should be done in the fall e.g., September to November each year. Samples MUST be collected the same way each year, e.g., the depth to which the sample is collected will influence the nutrient levels.

Assessing Soil Fertility

Armson (1973) lists three objectives of soil and plant tissue analysis which apply to monitoring seed orchard fertility.

1. To determine why a tree exhibits poor growth and/or organ abnormalities such as discoloration.
2. To detect nutrient deficiencies that inhibit growth in a tree or stand.
3. To control and regulate the nutrient supply to a tree necessary to produce a crop to meet specific objectives of management.

In seed orchards, it is unacceptable to wait until deficiency symptoms appear. Nutrient deficiencies that might inhibit tree growth and development must be detected before growth is seriously affected. Therefore, the third objective given by Armson (1973) is the most important.

Soil acidity (pH)

Soil acidity (pH), should range between 5.0 and 6.0 (Tables 5-1 and 5-2). At soil pH levels below 5.0, phosphorus availability decreases because of the formation of insoluble complexes with iron and aluminum (Armson 1979). The more soluble or available forms of P occur in soils of pH from 5.5 to 7.0. NOTE: Soil pH alone does not determine the lime requirements. The clay and organic matter content of the soil determines its buffering capacity and hence the amount of lime required to change the pH (see APPENDIX VI).

Organic matter content

The organic matter content influences the chemical characteristics and moisture holding capacity of the soil. Soils low in organic matter are more susceptible to compaction by machinery than soils with high organic matter content. The minimum level of soil organic matter in the orchard should be between 4 and 5% (Tables 5-1 and 5-2).

Table 5-1. Suggested soil fertility levels for seed orchards, Canadian Forestry Service laboratory

	Units	Recommended level[1]	Equivalent extractable nutrient (kg/ha)
pH	-	5.0 - 6.0	-
Organic matter	(%)	4.0 - 5.0	-
Cation exchange capacity	meq/100g	10 - 15	-
N	Total N (%)	0.10 - 0.15	1000 - 1500
P	Available P (ppm)	75 - 100	450 - 600 (P_2O_5)
K	Exchangeable K (meq/100g)	0.30 - 0.50	315 - 525 (K_2O)
Ca	Exchangeable Ca (meq/100g)	1.8 - 2.5	790 - 1100
Mg	Exchangeable Mg (meq/100g)	1.0 - 1.5	270 - 405
Ca/Mg ratio	4:1 - 10:1	-	

[1] Units as given on soils analysis lab report.

Table 5-2. Suggested soil fertility levels for seed orchards, Nova Scotia Agricultural College laboratory

	Units	Recommended level[1]
pH	-	5.0 - 6.0
organic matter	(%)	minimum 5.0
cation exchange capacity	meq/100g	-
N	Total N (%)	-
P	Extractable P (P_2O_5)	340 - 460 (kg/ha)
K	Exchangeable K (K_2O)	280 - 380 (kg/ha)
Ca	Exchangeable Ca	minimum 600 (kg/ha)
Mg	Exchangeable Mg	minimum 125 (kg/ha)
Ca/Mg ratio		maximum 5:1

[1] Units as given on soils analysis lab report.

Soil organic matter can be increased through either sowing a grain crop such as rye, oats, or buckwheat and plowing it into the soil or through organic amendments such as peat. The increase in organic matter content by additions of peat is difficult to determine reliably. Krause (1985) notes that applying peat at 200 m^3/ha corresponds to a 2-cm thick layer (this would correspond to a 6- to 8-cm thick layer of loose, bulk peat) and would raise the organic matter content by about 0.7% assuming that all was eventually incorporated into the soil.

Regardless of the method used, increasing soil organic matter content is expensive and must be done BEFORE either a cover crop is sown or orchard trees are planted.

Cation exchange capacity

The cation exchange capacity (CEC) of a soil is its capacity to hold and exchange positively charged particles (cations) which include the nutrients potassium (K^+), calcium (Ca^{2+}), magnesium (Mg^{2+}), ammonium (NH_4^+), hydrogen (H^+) and sodium (Na^+). The CEC of a soil is determined primarily from its clay and organic matter contents and should be between 10 and 15 meq/100 g.

Soils with a low CEC have a low water holding capacity, and lose N and K to leaching more readily than soils with a high CEC.

Soil macronutrients

The soil macronutrients include N, P, K, Ca and Mg. They are required in relatively large quantities by trees. Fertility recommendations for seed orchards in the Maritimes are based on tree growth and fertilization studies. The optimum soil and foliage nutrient levels for cone and seed production are not known but can be estimated.

Recommended soil fertility levels for seed orchards are presented separately for two laboratories. Soil fertility levels differ slightly between the two labs. These differences, however, arise largely from the assumptions used by the labs to calculate nutrient levels, e.g., soil bulk density, weight of soil per unit area, etc. and minor differences in their analytical methods (see MacDonald 1977; NSAC 1986). Orchard managers in these two provinces should determine their fertilizer requirements based on the nutrient levels reported from their respective labs. Soil samples from Prince Edward Island orchards are currently being analyzed at the CFS lab. Regardless of the laboratory being used to have soil samples analyzed, BE CONSISTENT.

1. Be consistent in how YOU sample, e.g., collect samples uniformly within and between blocks, collect all samples to the same depth, and by the same method each year.
2. Be aware of the methods used by the laboratory to which you submit soil/foliage samples.
3. Insist that the laboratory inform you if and when they change their analytical methods.
4. DO NOT CHANGE LABS FROM YEAR TO YEAR.

Correcting Nutrient Deficiencies

Once soil fertility levels have been determined, measures must be taken to correct any deficiencies. APPENDIX VI contains tables for fertilizer applications. Recommendations are provided for nutrients individually. APPENDIX VII contains some helpful hints on mixing your own fertilizers. This can reduce fertilizer costs.

Assessing Foliar Nutrient Levels

Soil macro- and micronutrient levels vary considerably between sites, depending on parent material, organic matter content, pH, etc. These factors not only affect the quantity of nutrients present in the soil but also their availability to the orchard trees. Therefore, while soil analyses determine the levels of nutrients in the soil, foliar analysis must also be done to determine whether or not the trees are actually obtaining adequate supplies.

Early research results have shown that there are differences in foliar nutrient levels between clones and families in white pine and jack pine respectively (Smith unpublished data). A similar pattern can be expected for many of our other species. To assess tree nutrition through foliar analyses, the number of samples collected must be sufficiently large to mask these genetic differences, e.g., samples must not be collected from only one or two clones or families.

1. For each species/sub-orchard/orchard block, randomly select 50 trees.
2. In September or October (after shoot lignification has ceased) , collect one current-year shoot from the upper one-third of the crown of each tree (Table 5-3). Tamarack foliage must be collected just prior to color change. Shoots should be collected from the same position in the crown for all trees (nutrient levels vary with height in the crown e.g., shoot vigor).
3. Combine all the shoots.
4. Put the foliage in paper bags, and label. NOTE: If the foliage is to be stored on-site for more than two or three days prior to shipping for analysis, then they should be put into plastic bags and frozen. However, do not leave the foliage in the plastic bags unfrozen!
5. Ship to the lab as soon as possible.
6. Foliage should be analyzed for the macronutrients (N,P,K,Ca,Mg). Suggested foliar nutrient levels are given in Table 5-4.

Optimizing Tree Growth

During the early years of orchard establishment, tree growth MUST be optimized. All other factors being equal, large trees will produce cones earlier and in greater quantities than small trees. Therefore, even though orchard soil fertility is assessed, and amendments made to bring nutrient levels up to desired levels, the individual trees should be fertilized regularly until their root systems fully occupy the site. For most clonal orchards in the Maritimes, this will take at least 5 to 10 years.

The following fertilization schedule was designed to ensure, as much as practicable, that the orchard trees receive an optimal supply of nutrients throughout the growing season (Table 5-5). DO NOT try to translate these individual-tree application rates to broadcast equivalents; the conversion on a per unit area basis would suggest fertilizer application rates much higher than normally advisable for broadcast applications.

Table 5-3. Foliage sampling for nutrient analysis. The suggested numbers of shoots to be collected is the minimum for the Canadian Forestry Service laboratory, and should provide ample material for other laboratories

Species	Wt./100[1] needles (g)	Approx. no. needles per 15 cm shoot	Minimum no. shoots required to obtain a 3 g sample oven dry wt
Black spruce	0.180-0.250	300-350	4-5
Red spruce	0.180-0.250	300-350	4-5
White spruce	0.180-0.250	300-350	4-5
Jack pine	0.500-0.600	150-175	3-4
Red pine	4.000-4.500	150-175	1-2
White pine	0.900-1.000	75-100	3-4
Tamarack[2]	0.050-0.075	100-125	10

[1] From M.K. Mahendrappa (unpubl. data).

[2] Absolute minimum; 10 shoots will not produce the full 3 g.

Table 5-4. Suggested foliar nutrient levels by species for seed orchards (from Mahendrappa unpubl. data). Orchard trees can be considered as being adequately supplied with the major elements if foliar levels are maintained within these ranges

	Element (% dry weight)				
Species	N	P	K	Ca	Mg
Black spruce	1.2 - 1.6	0.15 - 0.20	0.70 - 0.80	0.20 - 0.30	0.10 - 0.15
Red spruce	1.3 - 1.7	0.15 - 0.20	0.60 - 0.80	0.20 - 0.30	0.06 - 0.10
White spruce	1.3 - 1.7	0.15 - 0.25	0.70 - 0.80	0.20 - 0.30	0.06 - 0.10
Jack pine	1.2 - 1.6	0.15 - 0.20	0.60 - 0.80	0.20 - 0.30	0.06 - 0.10
Red pine	1.2 - 1.6	0.20 - 0.25	0.60 - 0.80	0.20 - 0.30	0.10 - 0.20
White pine	1.7 - 2.0	0.20 - 0.25	0.70 - 0.80	0.20 - 0.30	0.10 - 0.20
Tamarack	1.8 - 2.5	0.20 - 0.25	0.70 - 0.90	0.30 - 0.40	0.07 - 0.12

Table 5-5. Suggested schedule for fertilizing individual grafts in seed orchards

	Rate, type, and timing of fertilizer applications		
Stock type	Early to mid-May (2nd week)	Early to mid-June (2nd week)	Mid-July (2nd week)
New transplants (spring of year)	-	10-10-10 + ammonium nitrate (2:1 ratio)[1] rate: 30 g/graft	-
Small grafts (1-2 years from transplanting and older grafts of low vigor)	10-10-10 + ammonium nitrate (2:1 ratio) rate:30 g/graft	10-10-10 + ammonium nitrate (2:1 ratio) rate:30 g/graft	ammonium nitrate rate:15 g/graft
Established grafts	10-10-10 + ammonium nitrate (2:1 ratio) rate:50 g per 1.5 m of tree height	10-10-10 + ammonium nitrate (2:1 ratio) rate:50 g per 1.5 m of tree height	ammonium nitrate rate:15 g per 1.5 m of tree height

[1] 2:1 ratio by weight.

NOTES: Fertilizer should be applied in a band (evenly distributed) around each graft. The band should be located approximately half-way between the crown dripline and the stem or, when applicable, at the outside edge of the mulch. Do not DUMP the fertilizer at the base of the grafts. This can result in root damage and possibly kill small grafts!

If heavy spring rains follow the early May application, it may be desirable to refertilize the grafts at the same rates (heavy leaching losses). If this is done, the second scheduled application (mid-June) should be made one month following the refertilization.

Suggested Readings

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CHAPTER 6

PEST MANAGEMENT

Seed orchards must be protected from damaging agents. Potential seed losses can be minimized by isolating orchards from forests that provide natural habitats for harmful insects, birds, mammals, and alternate hosts of fungi. Adopting routine cultural practices such as close mowing of the cover crop (reduced small rodent habitat), and removing old cones (several cone and seed insects overwinter in old cones) will also afford some protection. All pest management operations must be recorded (APPENDIX IV). However, regardless of cultural practices, pests will invade the orchard.

Assessing Cone and Seed Losses

An effective means of quantifying the impact or potential impact of pests on a cone crop and concomitantly determining if a control program is warranted can be done through developing cone life tables. After the causes of losses have been IDENTIFIED and QUANTIFIED control efforts can be efficiently and cost-effectively undertaken. Generally, five steps are involved for each species in an orchard.

1. Select sample trees.
2. Obtain strobilus counts.
3. Periodically monitor strobilus/cone development and quantify the losses over the growing season.
4. Determine actual seed yields from those cones at the end of the growing season (at the end of the second year for pines).
5. Compare actual yields with expected yields to determine the percentage of the potential obtained.

APPENDIX VIII has detailed instructions on developing cone life tables.

The following system for monitoring cone and seed production is used to assess all aspects of seed production efficiency, not just the losses directly attributable to insects and diseases. Computer coding forms for this system are found in APPENDIX VIII.

1. Randomly select 10 ramets from each of five clones (10 seedlings from five families) for each species and/or suborchard. These 50 trees should be permanently tagged as they will be used each year whenever possible. However, some replacement trees (of the same family/clone) may be necessary as not all trees will bear strobili every year.
2. From early May to early June, preferably BEFORE pollination, depending on species, count the total number of female strobili on the sample trees. For large trees, tag two branches and count the strobili on them. The tagged branches should be in the middle portion of the female cone-bearing region of the crown, and should have AT LEAST 20 strobili each. Tag as many branches as necessary to obtain a total of 40 strobili.
3. About 1 to 2 weeks following pollination, use a hand lens to examine 10 strobili collected from each tree for the presence of eggs or larvae. Many insects that feed directly on cones and seeds lay eggs during the pollination period. If larvae or eggs are found, immediately send a sample to the Canadian Forestry Service - Maritimes, Forest Insect and Disease Survey (F.I.D.S) for identification (see APPENDIX VII).
4. In August/September count the mature cones on the sample trees/branches. For pines, conelets are counted in the fall of year one and mature cones the fall of the second year.
5. Collect 10 mature cones from each sample tree. Do a cut-test or extract the seed from these cones (see CHAPTER 7 for information on cone maturation and assessing seed quality).
6. Calculate the seed yield and compare these values with the expected seed yield (see APPENDIX VIII).

Insects and diseases

Insects and diseases in orchards can be grouped into two categories based on the type of damage they cause. Those that directly damage the cones and seeds and those that indirectly affect seed production through reducing tree growth and vigor. To minimize the damage caused by these agents, an orchard pest management system should be implemented to:

1. Monitor the insects and diseases and their population levels. Monitoring also detects the introduction of new pests.
2. Assess the damage they cause, or their potential for damage.
3. Determine if control measures are warranted.

Monitoring Insects and Diseases

Forest Insect and Disease Survey staff regularly visit seed orchards in the Maritimes. However, orchard staff must also conduct their own surveys. Ruth *et al.* (1982) give guidelines on how to sample and identify the major insect and disease pests in British Columbia seed orchards. Much of the information in this publication pertains to pests that are also potential problems in Maritime seed orchards.

The feeding periods of the insect pests of cones and seeds of Maritime tree species are shown in Fig. 6-1. When a problem or suspected problem is detected, follow these procedures:

1. Collect a sample. The sample should include some of the affected tissue (shoots, foliage) and WHEN PRESENT, the suspected pest (insects, spores, etc.).
2. Complete in detail a FIDS Seed Orchard Sample Submittal Form (a copy for reproduction is included in APPENDIX VIII, Fig. VIII-2).
3. Send both the sample and the completed form to Canadian Forestry Service Forest Insect and Survey, P.O. Box 4000, Fredericton, N.B. E3B 5P7. Mailing containers are available from your local office.

Controlling Insects and Diseases

Control of insects

There are two major classes of insecticides available, systemic and contact. Systemics such as dimethoate and carbofuran, when applied internally, or externally to the tree, are absorbed and translocated throughout the tree, rendering it toxic to insects. Systemic insecticides offer many advantages.

1. They are selective and minimize the effects on nontarget organisms such as beneficial parasites, predators, and pollinators.
2. They kill insects in roots, buds, galls, cones, bark, seeds, and leaves.
3. They often render the tree toxic to insects for long periods, thus reducing the number of applications required and sometimes eliminating the need for precise timing.

Systemic insecticides also have some disadvantages.

1. Extreme care in handling and application is required because of their high toxicity to humans and animals.
2. They may damage or kill plants if dosage recommendations are exceeded.
3. Insect control among closely related plant species is often erratic and ineffective because of intrinsic chemical and physical factors associated with each species and the soil on which it is grown (Merkel 1969). Some chemicals require one to two years buildup in the tree before they are effective in insect control. It may also be difficult to obtain high concentrations of insecticide in the cones.

Contact insecticides may provide sufficient protection depending on the type of insect involved and its ease of control. Cone and seed insects that do much of their damage while inside the strobili/cones are however, difficult if not impossible to control with contact insecticides.

There are currently NO insecticides registered for the control of cone and seed insects in forest tree seed orchards in the Maritimes. Dimethoate, for use on Douglas-fir, is presently the only chemical registered in Canada, specifically for the control of cone and seed insects in seed orchards. However, several experiments testing the efficacy of different chemicals in controlling cone and seed insects of Maritime tree species have been conducted. Results from these and other trials indicate that most of the pests thus far encountered in Maritime orchards can be effectively controlled by one or more insecticides. The major insect pests encountered to date in Maritime seed orchards and, where possible, 'promising' control measures are listed in APPENDIX IX.

These trials also indicate that if cone and seed insects in Maritime seed orchards are to be controlled effectively, orchard managers will require better tools than are currently available and better knowledge of the use of these tools. If these tools are to become available, registration must be obtained for the desired chemical(s). The demand for chemicals for orchard use is not likely to be sufficient to persuade most chemical manufacturers to conduct the research required for full registration. The most viable alternative is for Minor Use Registration. Taky (1986) provides details on Minor Use of Pesticides Program in Canada (copies of this publication are available from Agriculture Canada). Orchard managers in the Maritimes must make a coordinated effort to ensure that some of the chemicals with potential use in seed orchards are registered under this minor use program.

Control of diseases

Diseases may also affect orchards. Disease problems will be reduced by carefully selecting a proper site and practicing good sanitation techniques.

Needle rusts (*Pucciniastrum* spp.) may also pose a problem in orchards. They can cause defoliation and subsequent growth loss, however, they do not usually kill large trees. Needle rusts can cause considerable damage to cones and seeds (see Smith *et al.* 1986). To date, the use of fungicides in seed orchards to control needle rusts has not been required.

Spruce cone rust (*Chrysomyxa pyrolae* D.C.), which can pose a problem for all spruce species, is best controlled by eradicating the alternate hosts, plants in the wintergreen family (*Pyrola* spp. and *Moneses* spp.), within the vicinity of the orchard. Summers *et al.* (1986) obtained adequate control of a western cone rust (*C. pirolata*) in a white spruce seed orchard using the fungicide Ferbam. Ferbam 76 WDG was recently registered for use against spruce cone rust. One or two treatments applied between one week before pollination and the end of pollination, provided effective control and increased seed production in years of severe disease. However, there were some indications that the fungicide affected seed quality. Further studies on the effects of Ferbam on seed viability are needed.

Controlling Other Pests

Mammals and birds

Mammals and birds can also cause considerable damage to orchard trees. Voles and field mice, which girdle young trees, may be effectively controlled by close mowing of the cover crop and other vegetation (especially in the fall), but toxic baits are still the most effective method of controlling field mice (Peterson 1982). Examine the orchard in September or October for signs of mouse activity. Ontario Ministry of Agriculture and Food (1986) lists some of the mouse baits that are available as well as their application rates:

1. Waxed zinc phosphide bait- 5.5 to 11.0 kg/ha. If further mouse activity detected, repeat when rain is not expected.
2. Ramik Brown- 22 kg/ha in two applications of 11 kg with 20 to 40 days separating treatments.
3. Rozol paraffinized pellets (0.005% chlorophacinose) - 11 kg/ha.

To minimize the danger of poisoning nontarget animals such as birds and dogs, establish a series of feeding stations around the orchard. The bait can be placed in several types of containers including T-shaped pieces of PVC pipe, ice cream containers with holes cut in them, or styrofoam cups with holes (two cups with their tops taped together). Stations should be concentrated around the perimeter of the orchard (reducing influx of mice) and several stations should be located within the orchard to control existing populations.

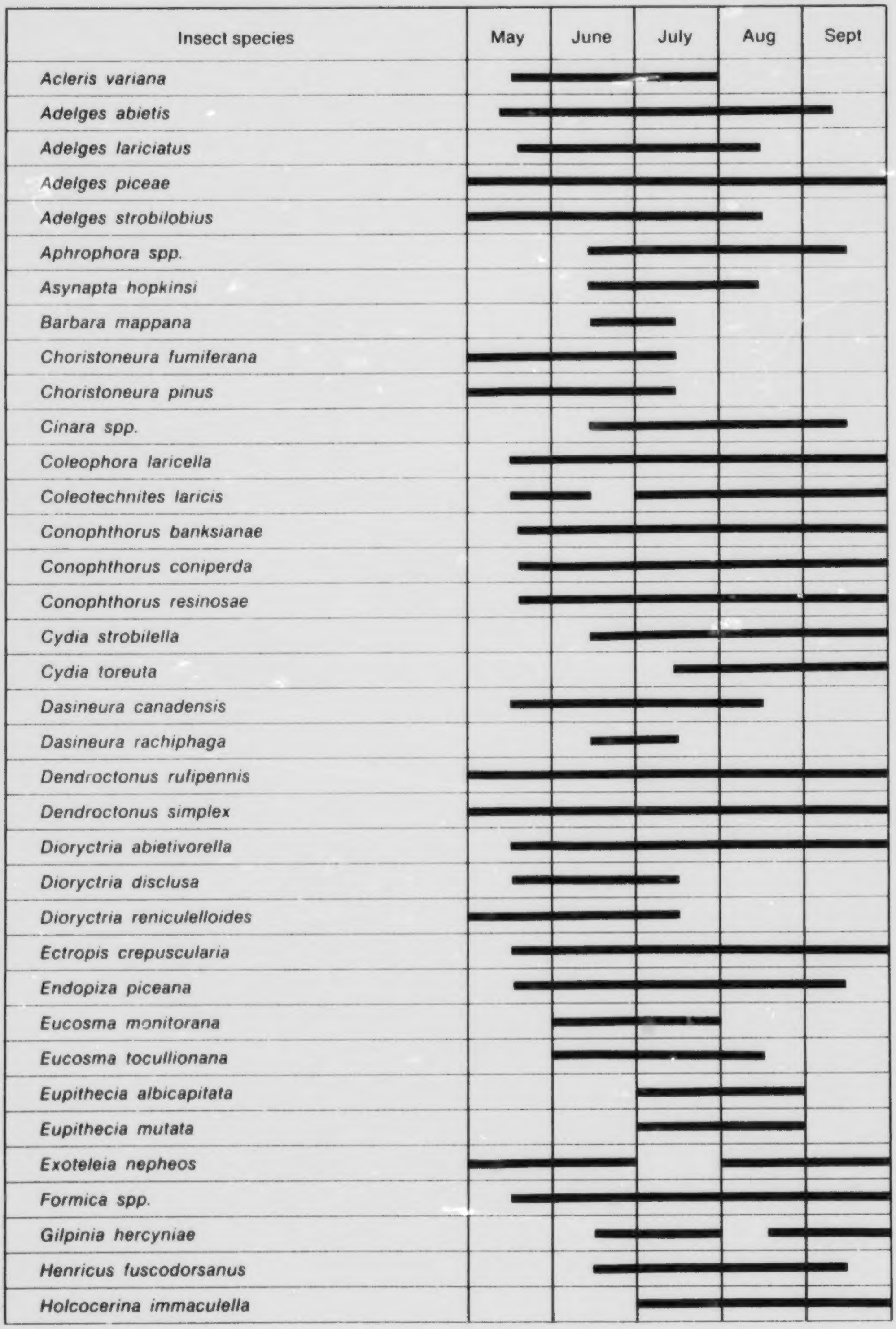
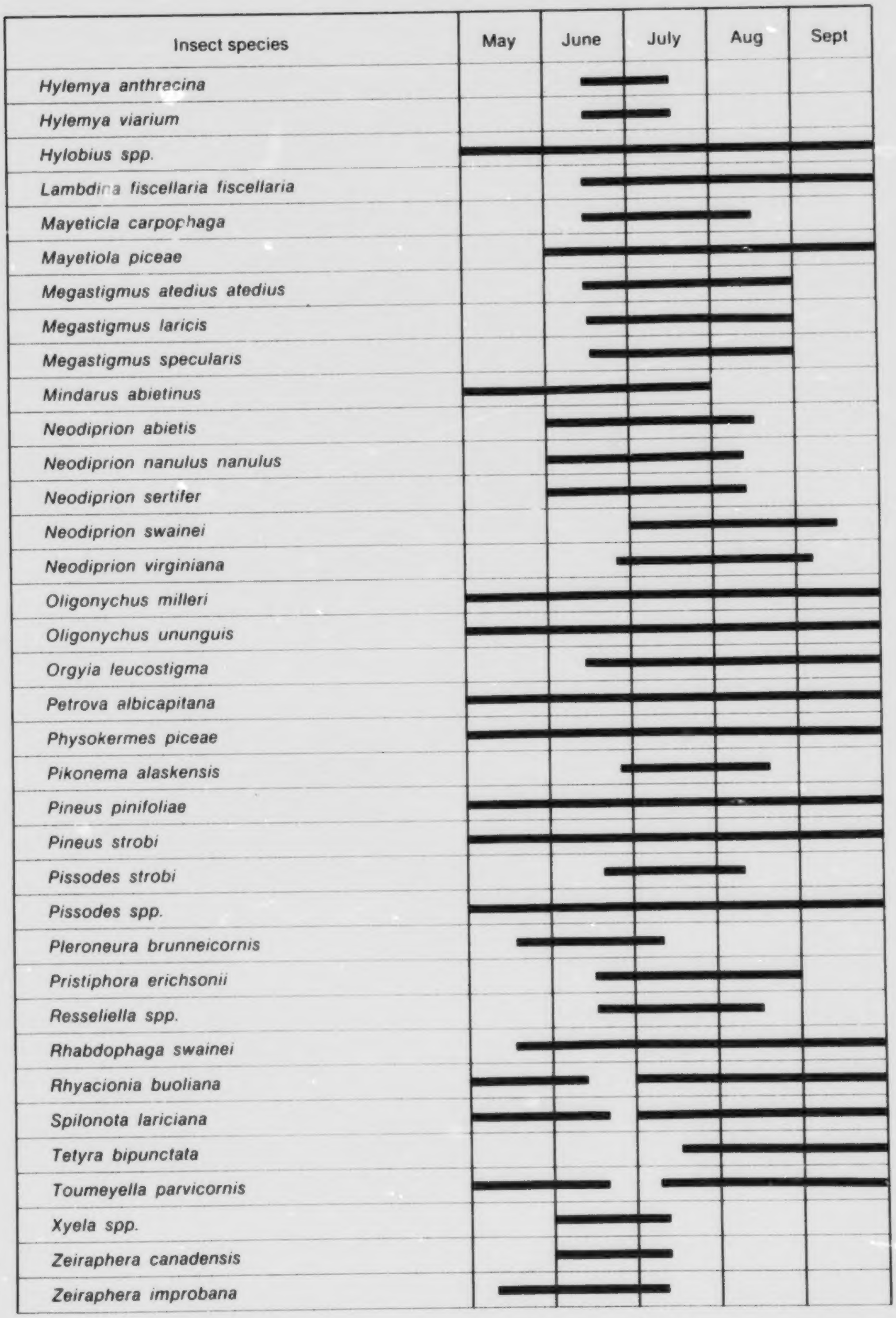


Figure 6-1. Major insect pests and their feeding times in Maritimes tree seed orchards (from Forest Insect and Disease Survey, 1986., unpublished data)


Insect species
May
June
July
Aug
Sept
Hylemya anthracina
Hylemya viarium
Hylobius spp.
Lambdina fiscellaria fiscellaria
Mayeticla carpophaga
Mayetiola piceae
Megastigmus atedius atedius
Megastigmus laricis
Megastigmus specularis
Mindarus abietinus
Neodiprion abietis
Neodiprion nanulus nanulus
Neodiprion sertifer
Neodiprion swainei
Neodiprion virginiana
Oligonychus milleri
Oligonychus ununguis
Orgyia leucostigma
Petrova albicapitana
Physokermes piceae
Pikonema alaskensis
Pineus pinifoliae
Pineus strobi
Pissodes strobi
Pissodes spp.
Pleroneura brunneicornis
Pristiphora erichsonii
Resseliella spp.
Rhabdophaga swainei
Rhyacionia buoliana
Spilonota lariciana
Tetyra bipunctata
Toumeyella parvicornis
Xyela spp.
Zeiraphera canadensis
Zeiraphera improbana

Snowshoe hare and porcupines, which chew bark off trees and squirrels which cut cones, can be controlled by placing metal bands around the stem of each tree. To be effective, bands must extend up the tree higher than the hares or porcupines can reach when standing on deep snow. Banding is expensive and is NOT practical in young seedling seed orchards (2500 stems/ha) before final rogueing or for small grafts. Small trees can be protected by surrounding them with chicken wire, hardware cloth, or plastic 'sleeves'.

Squirrels can do considerable damage to orchard trees, especially to jack pine. The squirrels often remove a strip of bark as they cut the cones, which frequently girdles branches. It is best to try to exclude them from the orchard by using one or more methods:

1. Poisoned bait.
2. Not allowing branches of adjacent trees to touch. This forces squirrels to climb each tree rather than moving between trees.
3. Maintaining a 30- to 40-m-wide bare strip around the orchard (increased predation). This is accomplished if a proper firebreak is maintained.
4. Placing bird perches around the orchard to attract birds of prey.

Fencing orchards is the most effective method to control deer browsing. However, fencing orchards is usually prohibitively expensive.

Birds perching on newly established grafts can be a serious problem, but one that is transitory, and diminishes as the grafts grow. Control techniques such as scaring, shooting, and the use of chemicals have had limited success. Perches may be placed throughout the orchard to discourage the birds from perching on the trees. There are no practicable methods to control birds such as pine grosbeaks which may feed on reproductive and vegetative buds. Limited control but at high cost can be achieved by using plastic sleeves on the branches.

Vandalism

Access to seed orchards by tree poachers, vandals, all-terrain-vehicles and snowmobiles is difficult to control. The best control can be obtained in those orchards which are completely fenced and when there is a person residing at the orchard year-round. However, for most orchards, this is not practical. Placing signs around the perimeter of the orchard indicating that the area is a seed orchard may act as a deterrent. Public education, including tours of the facility for local residents may be most beneficial. Employing a trusted and respected local resident to conduct periodic checks may also be worthwhile.

Fire

A firebreak, at least 15 - 20 m wide should be maintained around the orchard (see CHAPTER 1). For seedling seed orchards, all trees and shrubs must be removed from the firebreak. For clonal seed orchards, it can be maintained as a well-mowed green belt, but should not be kept vegetation-free because of potential soil erosion. Fire-fighting equipment should be available on site. A source of water such as a pond or well is also mandatory. During periods of high fire hazard, access to the orchard should be restricted.

Weather

The best method of reducing the liklihood of frost damage is to avoid high-risk sites. Frost can cause severe damage to emerging strobili in the spring. The orchard MUST be closely monitored during late spring when danger of frost damage is greatest. In general, strobili are most susceptible to frost damage from the time the bud cap starts to separate from the base of the bud (e.g., for spruces, when the reddish-purple color of the strobilus bracts is visible) to just after pollination (bracts closed).

The most effective method of monitoring temperature is to distribute temperature sensors such as maximum/minimum thermometers throughout the orchard. However, for most orchards, a weather station centrally located will suffice. This station should be equipped with a thermograph, a rain guage, and an anemometer. If the orchard has known frost pockets, then temperature should be monitored in these abnormal areas.

Above-tree mist-irrigation systems are effective in reducing frost damage. Other means of reducing frost damage include distributing heaters throughout the orchard and fanning the morning frosts with helicopters. All frost protection methods are expensive, but the potential ramification of doing nothing is to lose entire cone crops.

Snow and ice can cause serious damage to trees, especially young grafts. Staking each graft during the early years of development will minimize winter damage. Desiccation can also be a problem, especially on sites and in years when there is little snow cover. Snow fences distributed throughout the orchard perpendicular to the direction of the prevailing winds can be used to promote snow accumulation for a distance of 2-15 times the height of the fence depending on porosity. Good winter protection has been obtained by surrounding individual trees with burlap or feed bags with the bottoms cut open. Several stakes are placed around the grafts to ensure that the bags do not chafe the trees.

Suggested Readings

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Smith, R.F.; Magasi, L.P.; Harrison, K.J. 1986. Cone rust, a potential problem in white spruce seed orchards. Can. For. Serv.-Marit. Tech. Note No. 161.

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CHAPTER 7

CONE CROP MANAGEMENT

The objective of a seed orchard is to produce regular and abundant cone crops. Several techniques are available that can enhance cone and seed production but if the full benefits are to be realized, the cones must be harvested in a safe and efficient manner. Cone crop management operations must be recorded (APPENDICES IV, X).

Cone Crop Enhancement

The reproductive cycle of most local conifer species occurs over two successive calendar years, but for pines, it is three years (Figs. 7-1 and 7-2; APPENDIX XI). Benefits from treatments to enhance cone production will, therefore, not be realized for two or three years, depending on species.

Bud initiation and bud differentiation (see APPENDIX XII for definitions) are the phases in conifer reproductive cycles that are keys to the timing of any cone stimulation treatment. Cone stimulation treatments must be applied before initiation and/or differentiation if they are to be effective.

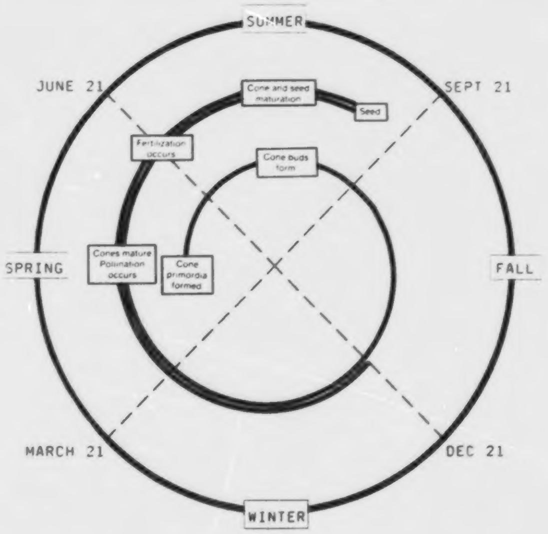
SUMMER
JUNE 21
SEPT 21
Cone and seed maturation
Seed
Fertilization occurs
Cone buds form
SPRING
FALL
Cones mature Pollination occurs
Cone primordia formed
MARCH 21
DEC 21
WINTER

Figure 7-1. The reproductive cycle of white spruce (adapted from Table 7-1).

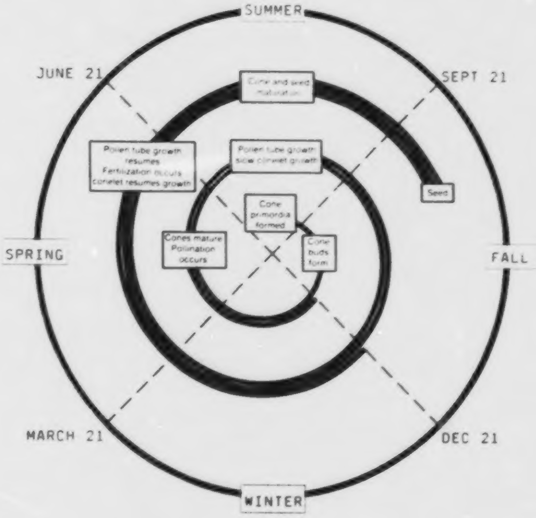
SUMMER
JUNE 21
SEPT 21
Cone and seed maturation
Pollen tube growth resumes Fertilization occurs conelet resumes growth
Pollen tube growth slow conelet growth
Seed
Cone primordia formed
Cones mature Pollination occurs
Cone buds form
SPRING
FALL
MARCH 21
DEC 21
WINTER

Figure 7-2. The reproductive cycle of jack pine (adapted from Table 7-1).

Estimates of times or periods of initiation and differentiation are given in Table 7-1 for average years in the Maritimes. A late or early spring will alter these times by as much as two weeks. Warm, southern locations tend to have earlier dates for initiation than cool, northern locations. Similarly, favorable aspects (southerly) elicit earlier development than less favorable aspects (northerly). The times of differentiation are less diverse than those of initiation. For the spruces, initiation occurs during the 10 days before vegetative buds burst, and differentiation occurs at or just after shoot elongation ceases.

Limited research has been conducted into cone and seed enhancement for species in the Maritimes. The recommendations given are based largely on trials with black spruce in New Brunswick, white spruce in Nova Scotia, and the remainder are from reports in the literature. A detailed review of the literature on many aspects of cone production in forest trees is available in Owens and Blake (1985).

Table 7-1. Estimates of times of periods of initiation of potentially reproductive buds, and of differentiation of reproductive structures within buds, for species growing in average conditions in the Maritime Provinces (Powell 1983 with modifications by personnal communications 1986)

Species	Initiation	Differentiation
Black spruce	Early to mid-June	Pollen cones: mid-July Seed cones: mid-July (to late July on young trees)
Red spruce	Early to mid-June	Pollen cones: mid-July Seed cones: mid-July (to late July on young trees)
White spruce	Late May to early June	Pollen cones: mid-July Seed cones: mid-July (to late July on young trees)
Jack pine	Potential pollen cones: continuous through June Potential seed cones: late July to late September	Pollen cones:continuous through August Seed cones: late September to late October
Red pine	Potential pollen cones: continuous from mid-June to late July Potential seed cones: late August to late September	Pollen cones:continuous through August Seed cones: late September to late October
White pine	Potential pollen cones: continuous from mid-June to late July Potential seed cones: September to late October	Pollen cones:continuous through August Seed cones: May to June of the next year
Tamarack[1]	Early May to mid-June	Pollen cones: mid-July to mid-August Seed cones: mid-July to late August

[1] Provisional dates. Investigations are continuing (Powell personal communication Dec. 1987).

Fertilizers

Fertilizing orchard trees to stimulate and enhance cone production has met with varying success but still is the most practical method available. Applying fertilizer to induce cone production is a separate treatment from fertilizing to alleviate nutrient deficiencies. The type of fertilizer may differ, and, in most cases, the rate and timing of application differ from fertility maintenance applications. There are several factors that influence the effectiveness of fertilizing to induce cone production in black spruce (Smith 1983; 1986). These factors also apply equally to other species.

Type of fertilizer

High nitrogen (N) fertilizers have been used successfully for inducing cone production, but not all types are equally effective. Ammonium nitrate increased cone production in black spruce whereas urea had no effect (Smith 1986).

Rate of fertilizer application

A sufficient amount of fertilizer must be applied before the desired effect is realized while over-fertilizing may not only fail to increase, but may actually decrease cone production. In black spruce, pollen production is particularly sensitive to over-fertilizing. Applying 200-300 kg N/ha as ammonium nitrate (240-360 g fertilizer/tree) to trees 12 to 16 years old increased both seed- and pollen-cone production whereas at higher rates (up to 600 kg N/ha) response was either absent or negative.

Timing of fertilizer application

Fertilizer should be applied at least 1- 2 weeks before bud differentiation (Table 7-1). This allows for the lag time between fertilizer application, dissolution and uptake.

Tree size

Large trees (height and diameter) generally produce more cones than small trees regardless of fertilizer treatment. Similarly, large trees require a higher fertilizer application rate than small trees to elicit the same response. Exact prescriptions for application of fertilizer per unit of tree size (e.g., per centimeter diameter) are not available for Maritime tree species.

Weather

Nitrogen fertilizers are water soluble. A heavy rainfall immediately following fertilization may negate the beneficial effects on cone production (Ebell 1972). Conversely, if there is a lack of moisture, the fertilizer may not reach the tree roots in sufficient time to effect a response that year.

Size of the current-year cone crop

Cone crops place a heavy nutrient demand on trees. The number of cones produced one year affects the potential number of buds produced the next year (number of potential cone production sites) (Powell 1977; Smith unpubl. data). A heavy cone crop one year is usually followed by a light crop the next.

Clone/family differences

Clones or families may differ greatly in their ability to produce cones. The magnitude of these genetic effects will be determined only when orchards are older, but studies from pine orchards in the southern United States indicate they could be considerable (Schmidtling 1983; Shoulders 1967).

Cover crop

Much of the fertilizer applied may be taken up by the cover crop thereby reducing the effect. When this occurs additional fertilizer will have to be applied to obtain the desired response (See CHAPTERS 3 and 4 on using mulch and herbicides to control vegetation around individual trees respectively).

Root pruning

Root pruning induces a water stress in the tree and has been effective in promoting formation of cone buds in both white and black spruce (Fraser 1975). Root pruning using spades or a single disc is usually done to a depth of about 15 to 20 cm. Care must be taken not to damage the trees severely. Only prune one or two sides per year. Some tree mortality may result from severe root-pruning, especially in dry years. Do not prune closer to the tree than the crown drip-line.

Root-pruned trees are temporarily weakened and may be more susceptible to infection from root rots. When pruning, whether by discs or spades, be sure to fill in the line of disturbance. Exposed roots increase the chance of attack by insects and disease. Trees that are repeatedly root-pruned may not be as wind-firm as unpruned trees and may be more susceptible to drought.

Girdling and strangulation

Girdling by making cuts in the tree or branch and strangulation by placing bands, usually metal, on the tree to constrict growth can induce water stress and affect the movement of carbohydrates and nutrients in the tree. Results from girdling and strangulation experiments have been variable, but it appears that, when timed properly, both can stimulate a 'one-time' heavy cone crop. However, these methods are not recommended in seed orchards. Tree mortality can result if damage is too severe and long-term cone production may be less on treated trees than on control trees because of the overall reduced vigor.

Growth hormones

In recent years, trials with growth hormones, particularly gibberellins, have been successful in enhancing both pollen and seed cones in many species. This is particularly useful for stimulating individual trees or clones to produce cones for use in breeding programs. Three major drawbacks to operational use of growth hormones in seed orchards are evident:

1. The concentrations most effective in field trials have sometimes resulted in problems with phytotoxicity associated with the surfactant.
2. Cost of the hormone is prohibitive.
3. The techniques for large-scale applications are not yet sufficiently refined.

However, hormones may be an important tool for seed orchard managers in the near future.

Topping trees

Topping trees by removing a maximum of 1-2 years growth at one time, while not a cone-induction treatment per se, may become important in Maritime seed orchards. Fast growing species such as tamarack can grow a metre or more per year when maintained under the high fertility regimes in seed orchards. Such trees quickly become too tall for easy cone harvesting. Top-pruning should begin at an early age. For most species in the Maritimes, this will probably be between age 7 and 10 years, whereas vigorous grafts of larch will require pruning before age 7. During the early years of orchard tree development trees can be topped regularly to promote large bushy crowns capable of carrying a large number of cones. However, topping may not be used in seedling seed orchards until they have been rogued at least once. The degree to which top-pruning can and should be used for Maritime tree species, needs to be further investigated.

Pollen Contamination

To maximize the genetic quality of the seed produced in an orchard, pollen contamination must be minimized. Studies in the southeastern United States indicate pollen contamination can be as high as 30-80%, even in mature orchards in which the trees are producing large quantities of pollen. This can reduce genetic gain by at least 2-4% (Friedman and Adams 1981). Preliminary studies in several Maritime orchards indicate background pollen levels are high.

For each orchard, establish a pollen monitoring system to determine the amount of contaminating pollen and to assess its potential impact on the quality of seed. Pollen arriving either before or after the period of strobilus receptivity is of little consequence.

1. Estimate background pollen levels by measuring pollen levels while the trees are young, BEFORE they produce significant quantities of pollen.
2. Continue monitoring pollen as the orchard trees mature. The difference between the two levels provides an estimate of within-orchard pollen production.

Greenwood and Rucker (1985) describe a reliable and inexpensive system for monitoring pollen contamination (Fig. 7-3).

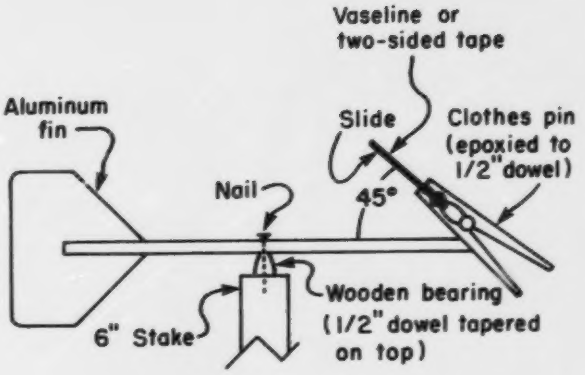
Vaseline or two-sided tape
Aluminum fin
Slide
Clothes pin (epoxied to 1/2" dowel)
Nail
45°
Wooden bearing (1/2" dowel tapered on top)
6" Stake

Figure 7-3. Diagram of a pollen trap (from Greenwood and Rucker 1985).

After pollen has been monitored for several years the necessity (or lack thereof) of implementing a program to reduce pollen contamination can be determined. Fashler and Devitt (1980) found that bud development in a Douglas-fir orchard could be delayed 10 to 14 days using an overhead irrigation system. This effectively eliminated about 85% of the pollen contamination. Supplemental Mass Pollination (SMP), the broadcast application of pollen, can be used to dilute the background pollen thus maximizing potential genetic gains, and to increase seed yields in orchards (Bridgewater and Trew 1981). The necessity for, and effectiveness of these types of management techniques for Maritime seed orchards has yet to be determined.

Cone Harvesting

Factors affecting costs of cone collecting are species (ease of collecting), tree size (method of collecting), number of cones per tree, and total number of trees. It is important to assess a cone crop well in advance of the time it is to be harvested and then use this information to ensure that sufficient funds and manpower are allocated.

Seed can be both physically and physiologically .damaged during cone collecting and handling. Considerable monies will have been spent before an orchard reaches the stage when cones can be collected. The orchard manager MUST maximize the quantity of seed collected from the orchard and ensure it is the best quality possible. DO NOT TREAT CONE HARVESTING CASUALLY.

Assessing the cone crop

The numbers of pollen and seed cones must be evaluated in the spring (strobilus counts) see APPENDIX X and again in late summer/fall (seed quality assessment). The same trees used for monitoring cone development should be used e.g., 10 ramets from each of five clones or 10 seedlings from five families (see CHAPTERS 5 and 6).

Although this sampling scheme gives reasonable estimates of cone crops with relatively few sample trees, in clonal orchards it gives only limited information about individual clones. Every clone is not represented. Orchards with many clones or families can be highly variable and may require a large number of sample trees. In contrast, rogued clonal orchards have fewer clones, so the variation within the orchards should be less and correspondingly, the number of sample trees required might decrease. Regular cone crop assessments can also be used in a young orchard to identify clones or families that are not fecund, and hence should be rogued.

In late summer seed yield per cone is assessed, usually with a cut test. Five of the 10 cones collected from each of the 50 sample trees should be cut in half longitudinally, and the number of exposed full seeds in one half of the cone counted (Table 7-2). A full seed should have an embryo about as long as the embryo cavity in the gametophyte, that is, almost as long as the seed itself. Until staff are experienced in doing cut-tests and extrapolating the results to actual seed yields, the seed from the other five cones from the sample trees should be extracted. When the staff is confident in the correlations between the two methods, only the cut-test will be necessary.

Table 7-2. Evaluating cone crop seed yields from a cut-test

Species	Number of full seed per half cone		
	Low	Medium	High
Black spruce	< 6	6-9	≥ 10
Red spruce	< 6	6-9	≥ 10
White spruce	< 6	6-9	≥ 10
Jack pine[1]	<10	10-15	≥ 16
Red pine	< 6	6-9	≥ 10
White pine	<10	10-15	≥ 16
Tamarack	< 2	2-4	≥ 5

[1] Slicing jack pine cones is difficult so it might be preferable to extract the seed.

The following describes a procedure for extracting seed from cones collected from the sample trees:

1. Air dry the cones in screened trays (plywood sides, screen bottom) under warm, dry conditions for 8 to 10 days.
2. After cones have opened shake out the loose seed. If they have not opened go to step 4.
3. If the cones are well opened, the remaining seed can be picked out of the cones with tweezers.
4. For species with resinous cones which may not open readily after air drying, soak the cones in hot tap-water for 15 to 20 minutes. Jack pine cones may be dipped in boiling water for 15 to 20 seconds.
5. Dry the wet cones in an oven at 50° C for 24 to 48 hours (until cones open). The oven should be well ventilated to allow moisture to escape.
6. Shake the dry cones, and pick out remaining seed.
7. Repeat steps 4 to 6 if necessary.

Determine the total number of full seed either with X-ray or a cut-test. The cut-test shows full seed as having a firm, white gametophyte with a distinguishable embryo.

The number of cones per tree and number of seeds per cone are used to estimate the total expected seed yield from the orchard, and to compare estimated seed yields with those actually obtained (see next section).

When orchards are young, seed production varies considerably between trees, often with most of the seed being produced by a small number of clones or families. Also, since little within-orchard pollen may be produced, the genetic quality of the seed may be low because of pollen contamination and/or self-pollination, or seed-set may be low because the orchard is well isolated from contaminating pollen. Although the quality of seed from such crops may be low, they must be collected to reduce habitat for cone and seed insects.

Time of collection

The time of year that seed embryos begin to mature is about the same for most conifer species in the Maritimes. However, the total time required for seed to mature, and the time at which cones should be collected varies considerably between species (Fig. 7-4).

High variability both between and within trees means that attempts at developing physical indices of cone maturity such as cone color and specific gravity have proven unreliable. The most reliable indicator of when cones are ready to be collected is the condition of the seed itself.

1. The gametophyte is opaque, white, and firm, NOT milky or liquid. Leave the cut seed overnight and if much shrinkage of the gametophyte occurs then the seed is not ripe.
2) The embryo should be 90% or more developed e.g., it should fill the embryo cavity.

Experience is necessary to assess seed maturity accurately. The time at which seed matures varies between trees and years. A cone-crop log should be kept for the orchard in which dates of seed maturity/cone harvesting are recorded (APPENDIX VIII). The log should also be used to correlate the time of seed maturation with tree growth and development and weather (growing degree-days). In New Brunswick, white spruce and tamarack cones can be safely collected when 1350 and 1150 degree days, respectively, have accumulated (Smith

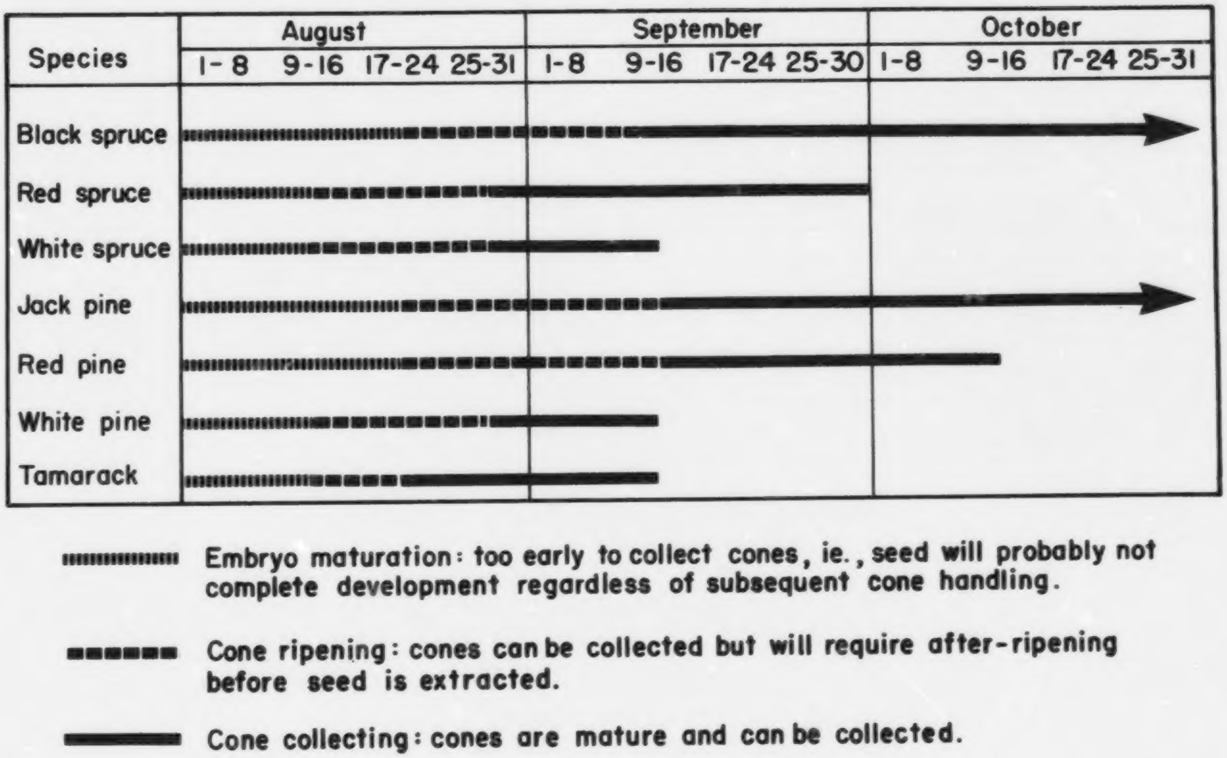

Figure 7-4. Cone and seed maturation stages for eight Maritime tree species. Development stages can be advanced 1 to 3 weeks with warm and dry weather and sites, and similarly retarded on cold and wet sites or where growing seasons are naturally later e.g., the Fundy shore (from Smith 1985).

1981;1983). Correlations of seed maturity with degree day accumulations should be determined for each orchard and each orchard species since seed will probably be shed earlier from orchard trees than from trees in mature stands.

How to collect

Cone collection crews must receive proper training in collection techniques (see Dobbs *et al.* 1976). Seed loss cannot be tolerated. Only cones and not shoots should be removed, because a shoot that bears seed cones one year, will eventually produce other shoots which will bear seed and pollen cones. Ease of removing cones from the shoots differs between species. Jack pine cones should be cut off with clippers because they are firmly attached by a stout stem making them difficult to remove by twisting and pulling, while white and red spruce cones are easily removed by the latter method.

Wnen trees are short, ladders, particularly tripods can be efficiently used to collect cones (Yeatman and Nieman 1978). As the trees grow, and access to cone producing parts of the crown is more difficult, hydraulic platforms and moveable scaffolds (scaffolds mounted on trucks) are necessary. 'Cherry-pickers' or bucket booms offer good maneuverability around tree crowns but are expensive to purchase and can compact the soil. Hallman and Casavan (1979) evaluate much of the equipment currently available for collecting cones. Most of the equipment reviewed has not been tested in the Maritimes.

Cone handling is an extremely important step in the cone collecting process. Cones must not be collected and stored 'wet'. They should be packed loosely in half filled burlap bags, placed in a well ventilated garage or cone-shed, and shipped as soon as possible to the extractory. Label each bag inside and outside according to species, orchard, sub-orchard or orchard block, date collected, and any other necessary information (see Smith 1985). The orchard managers' responsibility and interest in the seed should not stop when the cones are shipped to the extractory. The manager should ensure that:

1. The cones are stored properly at the extractory.
2. The extraction of the seed is both safe and efficient.
3. The seed yield information and results from any seed tests that have (or should have) been conducted are received.

This information combined with the other orchard records is necessary to assess orchard productivity accurately and to compare on-site estimates of seed yields and quality with those reported from the extractory. Over the long term, if these records are accurately maintained, the experienced orchard manager will know if the cones were handled properly after they left the orchard.

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APPENDIX I

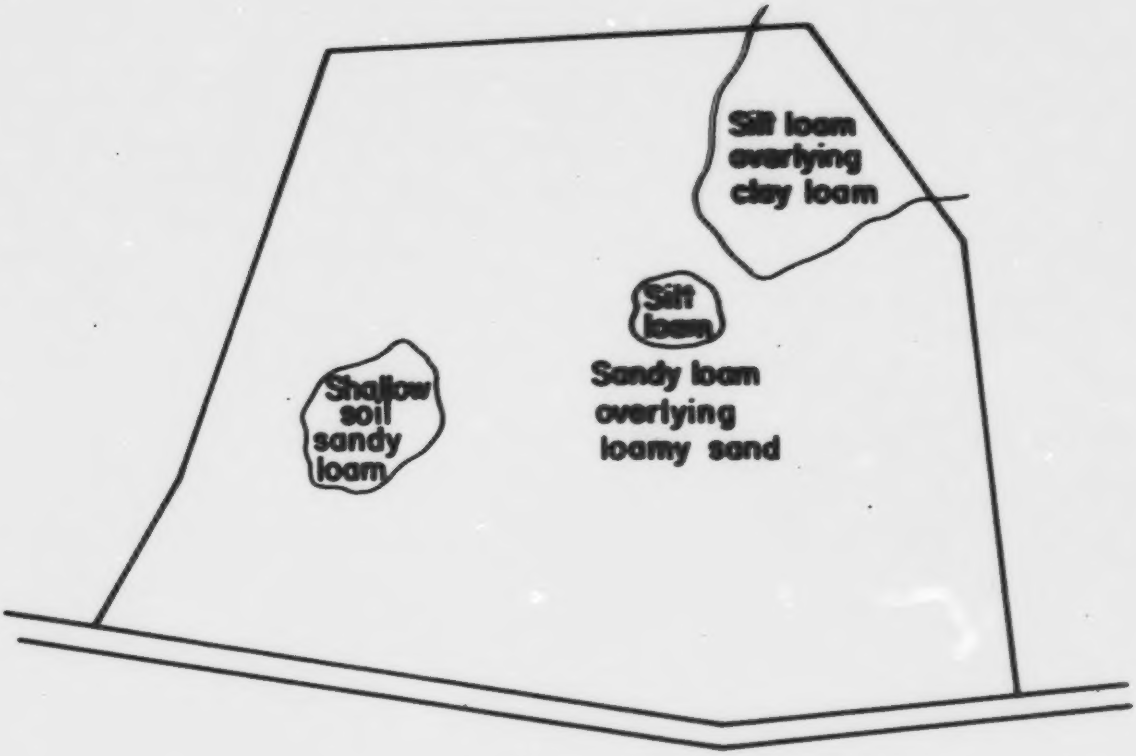
ORCHARD OVERLAY MAPS AND GENERAL SITE PLAN

Figure I-1. Soils

Figure I-2. Drainage

Figure I-3. Topography

Figure I-4. General site plan



Silt loam
overlying
clay loam
Silt
loam
Shallow
soil
sandy
loam
Sandy loam
overlying
loamy sand

Figure I-1. Orchard soils map overlay.

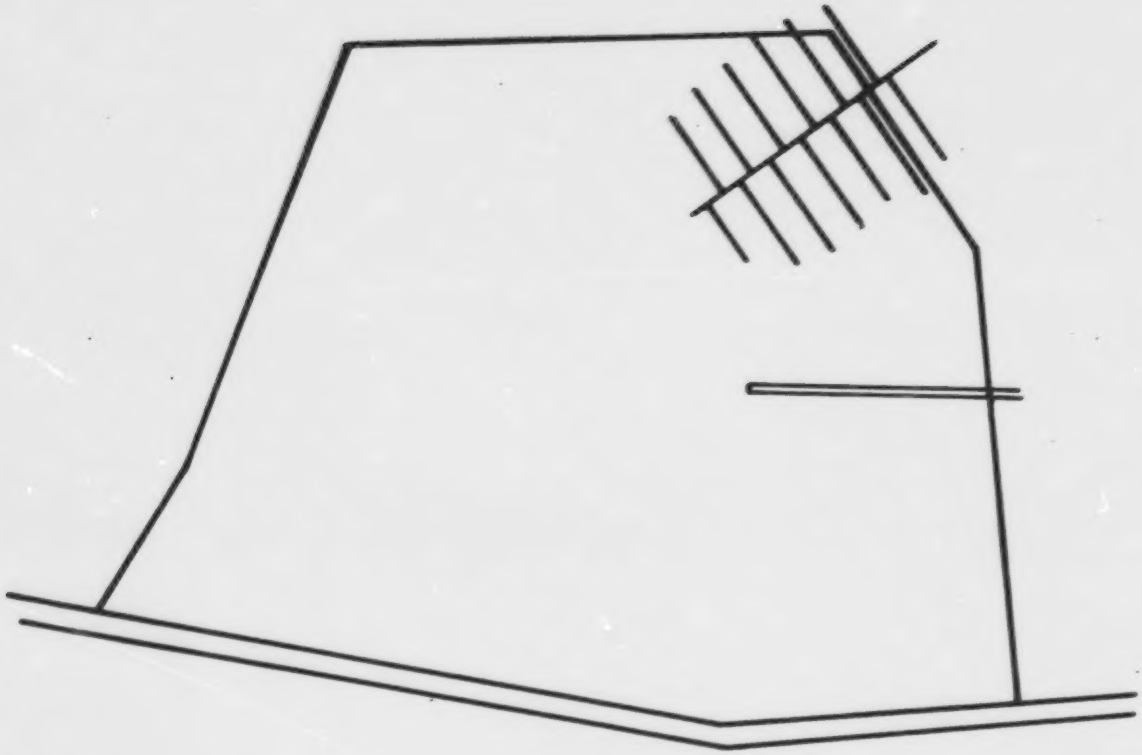


Figure I-2. Orchard drainage map overlay.

6

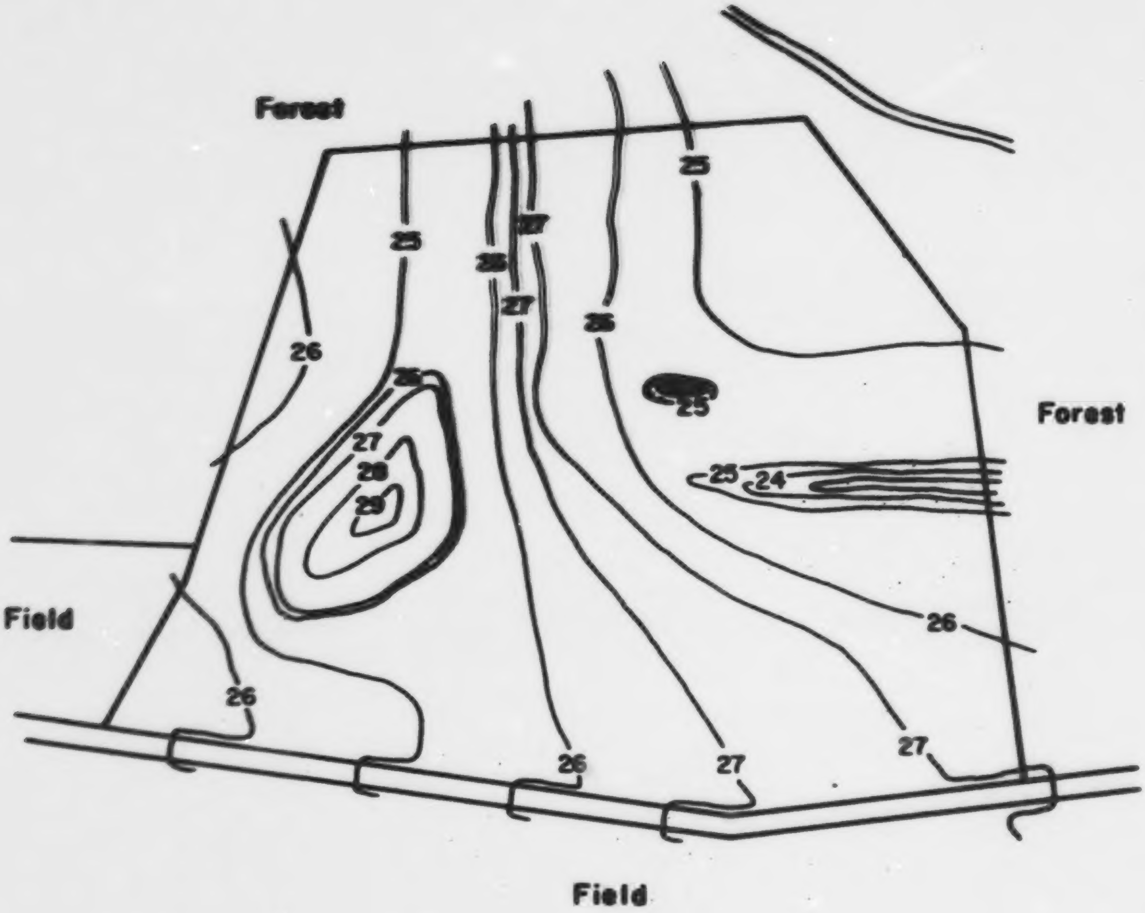

Forest
25
25
27
26
27
26
26
25
27
28
29
25
25
24
Forest
Field
26
26
26
27
27
Field

Figure I-3. Orchard topography map overlay.

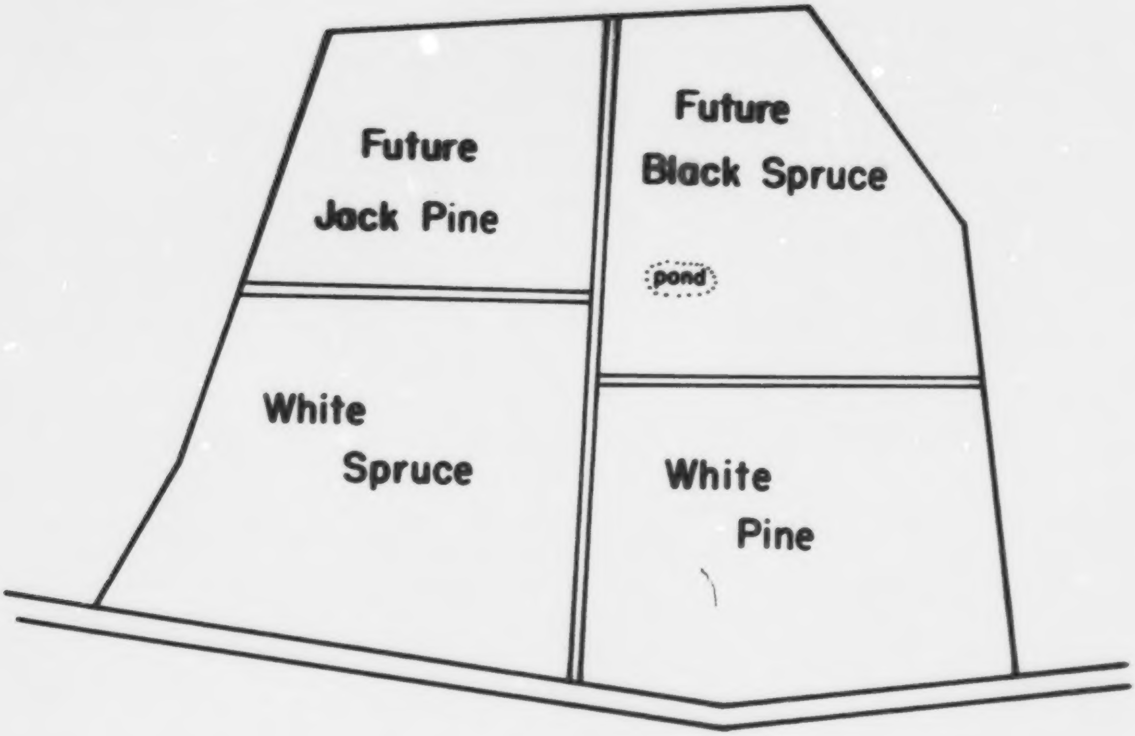

Future
Jack Pine
Future
Black Spruce
pond
White
Spruce
White
Pine

Figure I-4. Orchard general site plan map overlay.

APPENDIX II

CALCULATION OF SEED PRODUCING AREA OF A SEED ORCHARD

Species: white spruce
Orchard type: clonal
Required annual seedling production: 5 million
Grafts/ha: 275 (following final rogueing)

ASSUMPTIONS
No. cones/graft: 200
Sound seed/cone: 30
Seedling production method: container; 1.5 sound seed/seedling
Interval between cone crops: 2 years

No. sound seed/ha = (grafts/ha)x(no. cones/graft)x(sound seed/cone)
= 275 x 200 x 30
= 1,650,000 sound seed/ha

No. plantable seedlings = (no. sound seed/ha)/(no. sound seed/seedling)
= 1,650,000 / 1.5
= 1,100,000 plantable seedlings/ha

Area required to
produce seed for
1 million seedlings = (1,000,000 seedlings)/(1,100,000 seedlings/ha)
= 0.91 ha

Because of 2 year periodicity between cone crops, twice this area is required to produce enough seed for 1 million seedlings annually.

Total area required to produce
5 million seedlings/yr = 1.82 ha x 5
= 9.1 ha

This area requirement is dependent on the assumptions. For example, if the average number of cones per graft increases to 300 because of good management, then the orchard area requirement is reduced by one-third or if 2 full seed are required to produce a seedling, the orchard area is increased by one-third.

APPENDIX III

SEED ORCHARD SITE PREPARATION SUMMARY

Seed Orchard: ______________________________

Species: ______________ Block no.: ______________

Total area treated: ______________

Site History

Former cover type/land use: ______________________________

Date land cleared: ______________

Clearing method(s): ______________________________

____

____

Site Preparation

1. method: ______________ Date(s): ______________
2. method: ______________ Date(s): ______________
3. method: ______________ Date(s): ______________

Cover Crop Establishment

Plowing: ______________ Date(s): ______________

Harrowing: ______________ Date(s): ______________

Pre-sowing amendments:

Amendment	Rate	Application date

APPENDIX IV

SUMMARY OF ORCHARD OPERATIONS

Table IV-1 provides a form to record an annual summary of all operations conducted to aid the orchard manager in planning year to year operations and time and manpower requirements. The remarks section should contain general comments such as manpower used, time to complete work, area, block number, number of trees treated.

Operations to Include

- Establishment
  - planting
  - herbicide application
  - mulch application
  - graft pruning
- Vegetation management
  - cleaning
  - herbicide application
- Pest management
  - insect/disease monitoring
  - pesticide application
- Fertility management
  - broadcast applications
  - individual tree applications
  - soil/foliage sampling
- Cone crop management
  - monitoring/forecasting
  - pollen monitoring
  - fertilizer application
  - root pruning
  - hormone application
  - top pruning
  - harvesting

- Rogueing

- Grass mowing

- Graft staking/winter protection

Table IV-1. Annual summary of orchard operations

Year:

Operation	Date	Remarks

APPENDIX V

FERTILIZATION RECORDS

The Fertilization Record field sheet (Table V-1) can be used to record the day-to-day operations. This information is then copied onto the Fertilizer Application Record form (Table V-2) for computer entry. The Orchard Fertility Record form (Table V-3), is used to record results from soil and foliage analyses. After the data from these forms are entered in the computer, programs can be used to produce detailed fertility assessments/reports. These records can be updated as required.

NOTE: Although there are two separate forms, (convenience of data input), the data from both can be merged and a comprehensive summary produced. e.g., monitor changes in soil fertility levels with fertilizer applications.

Instructions for completing the Orchard Fertilizer Application Record - field sheet. All details regarding fertilizer applications should be recorded. Each form contains the data for one block and may be used for one or several years, as deemed necessary.

NOTES ON THE TYPE OF INFORMATION TO INCLUDE

I. Broadcast applications

Application date: Day, month, year

Application method: Type of equipment used e.g., drop-type (GANDY) spreader vs. cyclone spreader.

Fertilizer type: e.g., ammonium nitrate, 10-10-10, etc.

Fertilizer rate: e.g., 200 kg/ha.

Remarks: Make note of

1. Any 'problems' with applying the fertilizer e.g., equipment calibration. Can also note any equipment settings for future reference.
2. Weather e.g., very heavy rains shortly after applying fertilizer (especially important for fertilizers, such as ammonium nitrate, that are prone to heavy leaching losses).

II. Individual tree applications

Application date: Day, month, year

Fertilizer type: As per broadcast applications

Fertilizer rate: e.g., grams of fertilizer per tree

Fertilizer placement: e.g., band around the crown dripline, bands on two sides of the trees, etc.

Remarks: as per broadcast applications.

Table V-1. Orchard Fertilizer Application Record - field sheet.

FERTILIZATION RECORD

ORCHARD: ____________________

BLOCK: ________

BROADCAST APPLICATIONS					INDIVIDUAL TREE APPLICATIONS				
APPLICATION DATE	APPLICATION METHOD	FERTILIZER TYPE	FERTILIZER RATE	REMARKS	APPLICATION DATE	FERTILIZER TYPE	FERTILIZER RATE	FERTILIZER PLACEMENT	REMARKS

Instructions for completing the Orchard Fertilizer Application Record form.

Column No.

1-2 **Species:** Genera - species code

Le	Larch, European	Pw	Pine, white
Lj	Larch, Japanese	Sb	Spruce, black
Lt	Larch, tamarack	Sn	Spruce, Norway
Pj	Pine, jack	Sr	Spruce, red
Pr	Pine, red	Sb	Spruce, black

others as required

3-5 **Block/field number**

BROADCAST APPLICATIONS

6-15 **Fertilizer type:** use the nutrient contents of the fertilizer

6-7	% N
8-9	% P_2O_5
10-11	% K_2O
12-13	% Ca
14-15	% Mg

Listing of some common fertilizer types and their contents:

Fertilizer code	Common name
10-10-10	10-10-10 (triple 10)
15-15-15	15-15-15 (triple 15)
34-0-0	ammonium nitrate
46-0-0	urea
20-0-0	ammonium sulphate
0-46-0	triple-super-phosphate
0-0-48 (-17 sulphur)	potassium sulphate

etc.

16-21 **Date:**

16-17	Day
18-19	Month
20-21	Year

22-26 **Rate of fertilizer applied (kg/ha)**

INDIVIDUAL TREE APPLICATIONS

28-37 **Fertilizer type:** See cols. 6-15 above

38-43 **Date:** As above

44-48 **Rate:** grams fertilizer per tree or if fertilizer was applied in a band, specify the rate expressed as grams fertilizer per square metre, etc.

REMARKS

49-80 Note any factor that could affect the effectiveness of the fertilization operation, etc.

Table V-2. Orchard Fertilizer Application Record form.

ORCHARD FERTILIZER APPLICATION FORM

BLOCK		BROADCAST APPLICATIONS									INDIVIDUAL TREE APPLICATIONS									REMARKS
Species	NO.	FERTILIZER TYPE					DATE			RATE	FETILIZER TYPE					DATE			RATE	
		N	P_2O_5	K_2O	Ca	Mg	DD	MM	YY		N	P_2O_5	K_2O	Ca	Mg	DD	MM	YY		
1 2	3 4 5	6 7	8 9	10 11	12 13	14 15	16 17	18 19	20 21	22 23 24 25 26	28 29	30 31	32 33	34 35	36 37	38 39	40 41	42 43	44 45 46 47 48	49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80

Instructions for completing the Orchard Fertility Record form

Column No.		
1-2		**Species:** 2 letter species codes.
3-5		**Block/field number.**
6-10		**Nutrient:** expressed in the "form" reported N P, P_2O_5 K, K_2O Ca, CaO Mg, MgO pH Cation exchange capacity (C.E.C.) Organic matter (O.M.).
11-18		**Units** kg/ha, ppm, meq/100g, percent, etc.
19-20		**Soil/foliage.** Put an 'x' in the appropriate column.
21-26		**Date:** Date that the samples were collected.
	21-22	Day
	23-24	Month
	25-26	Year
27-32		**Level:** the nutrient level expressed in the units defined in cols. 11-18.
33-44		As per 21-32.
45-56		As per 21-32.
57-68		As per 21-32.
69-80		As per 21-32.

Table V-3. Orchard fertility record form.

ORCHARD FERTILITY RECORD

AGENCY: ____________________

ORCHARD: ____________________

BLOCK		NUTRIENT	UNITS	SOIL	FOL	DATE	LEVEL	DATE	LEVEL	DATE	LEVEL	DATE	LEVEL	DATE	LEVEL
SPECIES	NO					D D MM Y Y		D D MM Y Y		D D MM Y Y		D D MM Y Y		D D MM Y Y	
1 2	3 4 5	6 7 8 9 10	11 12 13 14 15 16 17 18	19	20	21 22 23 24 25 26	27 28 29 30 31 32	33 34 35 36 37 38	39 40 41 42 43 44	45 46 47 48 49 50	51 52 53 54 55 56	57 58 59 60 61 62	63 64 65 66 67 68	69 70 71 72 73 74	75 76 77 78 79 80

APPENDIX VI

TABLES FOR MANAGING ORCHARD FERTILITY

List of tables included:

Table VI-1. pH

Table VI-2. Phosphorus

Table VI-3. Potassium

Table VI-4. Calcium

Table VI-5. Magnesium

No attempt was made to assemble a nitrogen table because soil nitrogen varies with time of collection, organic matter content, etc.

Table VI-1. Soil pH (adapted from Meister 1984a)

Soil texture	Amount of dolomitic lime[1] (kg/ha) required to raise the pH 1 unit (assumes a 20 cm plow layer) pH 3.5-4.5	pH 4.5-5.5	pH 5.5-6.5
Sand and loamy sand	1000[2]	1250	1500
Sandy loam	-	2000	3200
Loam	-	3000	4200
Silt loam	-	3700	4900
Clay loam	-	4700	5700

[1] Recommendations are for a fine limestone e.g., all material passes through a 2-mm mesh and at least half passes through a 0.15-mm mesh. Coarser lime will require higher application rates. Recommended for soils in the classes of podzol, gray-brown podzol, brown forest, brown podzol, etc.

[2] Quantities rounded to the nearest 100 kg.

Table VI-2. Soil phosphorus. Available P_2O_5 calculated for a kg-ha-15cm.

Available P (ppm)	Amount of P_2O_5/ ha-15cm (kg)	triple super phospate required (kg/ha)	Amount of P_2O_5 added (kg/ha)	Comments
10	59	600	276	Do not apply more than 600 kg/ha
20	118	600	276	TSP in 1 yr as a surface dressing.
30	177	500	230	
40	236	375	173	May use up to 1000 kg/ha if applied
50	295	250	115	and incorporated prior to planting.
60	354	125	58	
70	413	-	-	Marginally acceptable P.
80	472	-	-	
90	531	-	-	Ample P.
100	590	-	-	

Table VI-3. Soil potassium. Available K_2O calculated for a kg-ha-15cm.

Exchangeable K meq/100 g	K_2O/ha-15cm (kg)	Amount of K_2SO_4 required (kg/ha)	Amount of K_2O added (kg/ha)	Comments
0.05	61.3	300	147	Very low. May require a 2nd application. Do not apply more than 300 kg/ha K_2SO_4 in one year as K leaches readily.
0.10	122.6	300	147	
0.15	183.9	300	147	
0.20	245.2	250	123	
0.25	306.5	150	74	
0.30	367.8	100	49	Low K.
0.35	429.2	50	25	
0.40	490.5	-	-	
0.45	551.8	-	-	
0.50	613.0	-	-	

Table VI-4. Soil calcium. Available CaO calculated for a kg-ha-15cm.

Exchangeable Ca meq/100 g	CaO ha-15cm (kg)	Amount of dolomitic lime required (kg/ha)	Amount of CaO added (kg/ha)	Comments
0.4	294	3000	1128	
0.6	440	2000	752	
0.8	587	2000	752	
1.0	733	1000	376	
1.2	880	1000	376	
1.4	1027	1000	376	Marginally acceptable
1.6	1173	1000	376	
1.8	1320	-	-	
2.0	1466	-	-	
2.2	1612	-	-	
2.4	1760	-	-	
2.6	1907	-	-	

Note: The Ca:Mg ratio should not exceed 10:1. Therefore the Ca and Mg levels should be evaluated together. The pH of the soil must also be considered before applying dolomitic lime.

Table VI-5. Soil magnesium. Available MgO calculated for a kg-ha-15cm.

Exchangeable Mg meq/100 g	MgO ha-15cm (kg)	Amount of dolomitic lime required (kg/ha)	Amount of MgO added (kg/ha)	Comments
0.1	52	3000	704	
0.2	104	2000	569	
0.3	156	2000	469	
0.4	209	1000	235	
0.5	261	1000	235	
0.6	313	1000	235	Marginally acceptable
0.8	417	1000	235	
1.0	521	-	-	
1.2	626	-	-	
1.4	730	-	-	
1.6	834	-	-	

Note: The Ca:Mg ratio should not exceed 10:1. Therefore the Ca and Mg levels should be evaluated together. The pH of the soil must also be considered before applying dolomitic lime.

APPENDIX VII

MIXING YOUR OWN FERTILIZERS

Fertilizers can be mixed in different ratios depending on how much nutrient you want to apply per given area.

These mixes will have the nutrients in the same proportions as commercial mixes. However, LESS total material will have to be applied to obtain the same nutrient additions than were a commercial mix used.

Advantages of mixing your own fertilizers.

1. It is usually cheaper on a per kilogram nutrient basis, to purchase fertilizers separately and mix your own than it is to purchase the premixed fertilizers. Commercial mixes use sand or a similar filler to make up the volume. When you mix your own, you do not pay for fill.
2. You have the flexibility to make different mixes and/or to apply the separate nutrients.

Drawbacks arise because you need to purchase several different fertilizer types (need to buy in bulk) and you require the equipment to mix the materials. THEY MUST BE MIXED THOROUGHLY!!!! e.g., in a large cement mixer.

Examples of how several single-element fertilizers can be combined to produce a desired mix are given below.

Fertilizer type	Formula	Actual nutrient content
Ammonium nitrate	34-0-0	= 34% N
Potassium sulphate	0-0-48	= 48% K_2O
Triple-super-phosphate	0-46-0	= 46% P_2O_5

Calculations

1. Start with the fertilizer with the nutrient which has the lowest percentage e.g., ammonium nitrate 34% (versus 48% K_20 and 46% P_2O_5).

2. Calculate ratios of the nutrient percentages, i.e., smallest over each of the other two:
   34/48 = 0.71
   34/46 = 0.74

3. The proportions (by weight) of the three fertilizers which must be added to obtain a balanced mix, e.g., 10-10-10, would then be

ammonium nitrate	1.00
potasium sulphate	0.71
triplesuperphosphate	0.74

Example I

A 10-10-10 fertilizer contains 10% N, 10% K_2O, and 10% P_2O_5 and if you wanted to apply the equivalent of 500 kg/ha of 10-10-10

500 kg X 0.10 = 50 kg N

50/0.34 = 147 kg ammonium nitrate required to add the same total amount of elemental nitrogen (N).

Therefore the mix would be

1.00 X 147 = 147 kg ammonium nitrate
0.71 X 147 = 104 kg potassium sulphate
0.74 X 147 = 109 kg triplesuperphosphate

From the practical standpoint the quantities would be rounded. You would only be applying 360 kg fertilizer mix whereas with the premixed 10-10-10 you would have to apply 500 kg.

Example II

If you want to apply the equivalent of 500 kg/ha of 10-10-10

Fertilizer type	Formula	Actual nutrient content
Urea	46-0-0	= 46% N
Potassium sulphate	0-0-48	= 48% K_2O
Triplesuperphosphate	0-46-0	= 46% P_2O_5

46/46 = 1.00
46/48 = 0.96
46/46 = 1.00

Ratios

urea	1.00
potasium sulphate	0.96
triplesuperphosphate	1.00

500 X 0.10 = 50 kg N

50/.46 = 109 kg urea required to add the same total amount of elemental nitrogen (N).

Therefore the mix would be

1.00 X 109 = 109 kg urea
0.96 X 109 = 105 kg potassium sulphate
1.00 X 109 = 109 kg triplesuperphosphate

You would apply only 323 kg fertilizer mix whereas with the 10-10-10 premix you would apply 500 kg.

Note: For all practical purposes, the percent nutrient content for these three are close enough that they can be mixed equally and produce a balanced mix.

APPENDIX VIII

MONITORING CONE LOSSES

Strobilus and cone pest damage assessments, and instructions for constructing cone life tables. The assessment codes for insects and diseases include most pest species directly attacking cones and seed of Maritime conifer species.

Instructions for completing Figure VIII-1, Damage Assessment Form.

Column No.	
1-21	**TREE IDENTIFICATION**
1-2	**Orchard Number:** Agencies with several different orchard sites or suborchards within a single complex may wish to assign a 2-digit code to distinguish them.
3-4	**Species:** Genera-species code.

Lt	Larch, tamarack
Pj	Pine, jack
Pr	Pine red
Pw	Pine, white
Sb	Spruce, black
Sn	Spruce, Norway
Sr	Spruce, red
Sw	Spruce, white

Other codes can be developed as required.

5-7	**Block**	
8-10	**Row**	These entries are used to locate EXACTLY which tree was sampled. This makes identifying the same tree easier.
11-13	**Column**	
14-19	**Clone/family no.**	
20-21	**Cone year:** The year the strobili first appear.	

22-26 DAMAGE ASSESSMENT

The damage assessment columns are repeated 3 times, e.g., allows for sampling 3 times in the same year. For pines, sampling is done over two years, a separate line is used per year.

22-25 **Strobili/cone (number):** Counts of the numbers of healthy and damaged strobili/cones (see CHAPTER 7 for sampling scheme), e.g., If 20 strobili tagged

Strobili/cone number	Pest	Spp.	ID
15	00	00	N
3	01	C1	N
2	01	D1	Y

If desired, more intensive sampling may be done, e.g., conelet tagged individually and its position noted.

0101	whorl 1	conelet #1
0102	whorl 1	conelet #2
0201	whorl 2	conelet #1
0202	whorl 2	conelet #2

This system applies more to a research study than to operational monitoring. However, the results can be used for operations as well.

26 **Branch number:** If individual branches are tagged, a separate number is used for each.

27-66 DAMAGE CODE

27-28 **Pest:** Number code to distinguish the type of damage (if any) observed. See Table VIII-1 for a suggested coding system.

29-30 **Species:** A combined letter-number code to identify the pest species (Table VIII-2).

e.g., A1 *Adelges abietis*

If more than one pest is found in one cone, then each should (can) be listed separately and noted in the comments section. The number of healthy cones is the check to ensure the total is not changed.

31 **ID:** In many instances, the orchard manager will not be able to identify the insect species on the samples. When this occurs the sample should be shipped to the local FIDS office for identification. The ID code can be used to indicate whether or not a sample was sent to FIDS.

Y - Yes
N - No

A copy of the form for submitting samples to FIDS is given in Fig. VIII-2.

32-36 Date sampled

37-51 as per 22-36 above.

52-66 as per 22-36 above.

67-80 COMMENTS

General notes on developmental abnormalities, etc. Other cross-reference notes should be made here (e.g., branch damaged after sampling). Agencies can develop their own coding system for comments, e.g.,

brdam	branch damaged after sampling

Table VIII-1. Pest codes.

Pest code	Assessment	
00	Cones healthy, no evidence of insects, disease or other damage	
01	Insects either present or evidence of insect damage	
02	Diseases	
03	Weather	e.g., frost damage
04	Mechanical damage	e.g., damage to shoots, breakage of cone axis
05	Abortion	e.g., physiological (insufficient pollen)
06	Unknown	

Table VIII-2. Species codes.

Species code	Scientific name	Common name
		INSECTS
A1	*Acleris variana*	eastern blackheaded budworm
A2	*Adelges abietis*	eastern spruce gall aphid
A3	*Adelges lariciatus*	spruce gall adelgid
A4	*Adelges strobilobius*	pale spruce gall adelgid (on larch)
A5	*Adelges piceae*	balsam woolly aphid
A6	*Aphrophora spp.*	spittlebugs
A7	*Asynapta hopkinsi*	cone resin midge
B1	*Barbara mappana*	cone moth
C0	*Choristoneura fumiferana*	spruce budworm
C1	*Choristoneura pinus*	jack pine budworm
C2	*Cinara spp.*	aphids
C3	*Coleophora laricella*	larch casebearer
C4	*Coleotechnites laricis*	larch needle tubemaker
C5	*Conophthorus banksianae*	jack pine tip beetle
C6	*Conophthorus coniperda*	white pine cone beetle
C7	*Conophthorus resinosae*	red pine cone beetle
C8	*Cydia strobilella*	spruce seed moth
C9	*Cydia toreuta*	eastern pine seedworm

Species code	*Scientific name*	Common name
D1	*Dasineura canadensis*	spruce cone gall midge
D2	*Dasineura rachiphaga*	spruce cone axis midge
D3	*Dendroctonus simplex*	eastern larch beetle
D4	*Dioryctria abietivorella*	fir coneworm
D5	*Dioryctria disclusa*	webbing coneworm
D6	*Dioryctria reniculelloides*	spruce coneworm
E1	*Ectropis crepuscularia*	saddleback looper
E2	*Endopzia piceana*	spruce micro moth
E3	*Eucosma monitorana*	red pine cone worm
E4	*Eucosma tocullionana*	white pine cone worm
E5	*Eupithecia albicapitata*	spruce cone geometer
E6	*Eupithecia mutata*	spruce cone geometer
E7	*Exoteleia nepheos*	pine candle moth
F1	*Formica spp.*	ants
G1	*Gilpinia hercyniae*	European spruce sawfly
H1	*Henricus fuscodorsanus*	cone cochylid
H2	*Holcocerina immaculella*	conifer micro moth
H3	*Hylemya anthracina*	spruce cone maggot
H4	*Hylemya viarium*	larch cone maggot
H5	*Hylobius spp.*	root weevils
L1	*Lambdina fiscellaria fiscellaria*	hemlock looper
M1	*Mayetiola carpophaga*	spruce seed midge
M2	*Mayetiola piceae*	spruce gall midge
M3	*Megastigmus atedius atedius*	spruce seed chalcid
M4	*Megastigmus laricis*	larch seed chalcid
M5	*Megastigmus specularis*	balsam fir seed chalcid (also on white pine)
M6	*Mindarus abietinus*	balsam twig aphid
N1	*Neodiprion abietis*	balsam fir sawfly
N2	*Neodiprion nanulus nanulus*	red pine sawfly
N3	*Neodiprion sertifer*	European pine sawfly
N4	*Neodiprion swainei*	jack pine sawfly
N5	*Neodiprion virginiana*	redheaded jack pine sawfly
O1	*Oligonychus milleri*	spider mite
O2	*Oligonychus ununguis*	spruce spider mite
O3	*Orgyia leucostigma*	whitemarked tussock moth

Species code	Scientific name	Common name
P1	*Petrova albicapitana*	northern pitch twig moth
P2	*Physokermes piceae*	spruce bud scale
P3	*Pikonema alaskensis*	yellowheaded spruce sawfly
P4	*Pineus pinifoliae*	pine leaf aphid
P5	*Pineus strobi*	pine bark adelgid
P6	*Pissodes strobi*	white pine weevil
P7	*Pissodes spp.*	root weevils
P8	*Pleroneura brunneicornis*	balsam shootboring sawfly
P9	*Pristiphora erichsonii*	larch sawfly
R1	*Resseliella spp.*	midges
R2	*Rhabdophaga swainei*	spruce bud midge
R3	*Rhyacionia buoliana*	European pine shoot moth
S1	*Spilonota lariciana*	brown larch tubemaker
T1	*Tetyra bipunctata*	shield-backed pine seed bug
T2	*Toumeyella parvicornis*	pine tortoise scale
X1	*Xyela spp.*	xyelid sawflies
Z1	*Zeiraphera canadensis*	spruce bud moth
Z2	*Zeiraphera improbana*	larch needleworm
	DISEASES (FUNGI)	
01	*Armillaria mellea*	armillaria (shoestring) root rot
10	*Chrysomyxa ledi*	needle rust
11	*Chrysomyxa ledicola*	needle rust
12	*Chrysomyxa pyrolae*	spruce cone rust
13	*Coleosporium asterum*	needle rust
14	*Cronartium ribicola*	white pine blister rust
20	*Endocronartium harkenessii*	globose gall rust
30	*Gremmeniella abietina*	scleroderris canker
40	*Lachnellula willkommii*	European larch canker
41	*Lirula macrospora*	needle cast
42	*Lophodermium piceae*	needle cast
50	*Pucciniastrum americanum*	spruce needle rust
60	*Sirococcus strobilinus*	sirococcus shoot blight

Figure VIII-1. Damage assessment form.

TREE IDENTIFICATION							DAMAGE ASSESSMENT																		COMMENTS
ORCHARD NUMBER	SPECIES	BLOCK	ROW	COLUMN	CLONE/ FAMILY NUMBER	CONE YEAR	STROBILI /CONES (NO.)	BRANCH	DAMAGE CODE			DATE SAMPLED	STROBILI /CONES (NO.)	BRANCH	DAMAGE CODE			DATE SAMPLED	STROBILI /CONES (NO.)	BRANCH	DAMAGE CODE			DATE SAMPLED	
									PEST	SPP	ID				PEST	SPP	ID				PEST	SPP	ID		
1 2	3 4	5 6 7	8 9 10	11 12 13	14 15 16 17 18 19	20 21	22 23 24 25	26	27 28	29 30	31	32 33 34 35 36	37 38 39 40	41	42 43	44 45	46	47 48 49 50 51	52 53 54 55	56	57 58	59 60	61	62 63 64 65 66	67 68 69 70 71 72 73 74 75 76 77 78 79 80

Figure VIII-2. Seed orchard Forest Insect and Disease Survey (F.I.D.S.) sample submittal form.

SEED ORCHARD SAMPLE SUBMITTAL FORM

(To Accompany Each Sample Submitted For Identification)

A. CORRESPONDENCE TO BE ADDRESSED TO:

____

____

Telephone: ________________ Collector: ________________

B. SAMPLE (SEND ONLY ONE HOST PER SAMPLE):

Seed Orchard ________________________

Host (species) ____________ Date Collected ____________

Type of sample (no.) Soil ______ Foliage ______ Cone ______

Stock Type: graft ______ rooted cutting ______ seedling ______

other (describe) ________________________

Number of ramets/clone or seedlings/family sampled ____________

Describe how the samples were collected: e.g. for soils-state whether composities were made or just single cores, depth of soil sample; for foliage-where in the crown foliage was collected, etc...

____

____

____

NOTE: It is recommended that both soil and foliage samples be collected when nutrition, or other abiotic problems are suspected.

C. PROBLEM:

Percent (or number) of affected trees in affected area:

____

____

CONDITION: Describe problem: include information on first appearance, present symptoms, rate of spread, mortality, unusual problems (such as soil nutrient, water or climate), etc. Be as complete as possible, include helpful "hints".

____

____

____

____

____

D. DELIVERY: Include submittal form, mark package PERISHABLE and send to: Forest Insect and Disease Survey, Canadian Forestry Service - Maritimes, P.O. Box 4000, Fredericton, N.B. E3B 5P7.

E. OFFICE USE ONLY: Date received ____________ Insect/Disease/Other

Pest ID: ________________________

Register No. ____________ Culture No. ____________

Receipt ackn'd (Date): ____________ To RFS (Date): ____________

Date Replied: Phone ________ by ______ Letter ______ by ______

Instructions for completing Figure VIII-3 Seed Yield form, and examples of cone life tables based on the procedures given in Bramlett and Godbee (1982). The data from Figures VIII-1 and VIII-3 can be combined in the computer and all necessary calculations performed.

Instructions for completing Figure VIII-3, Seed Yield Form.

Column No.

1-21 TREE IDENTIFICATION

1-2 **Orchard Number:** Agencies with several different orchards sites or sub-orchards within a single complex may wish to assign a 2-digit code to distinguish them.

3-4 **Species:** Genera-species code.

Lt	Larch, tamarack
Pj	Pine, jack
Pr	Pine red
Pw	Pine, white
Sb	Spruce, black
Sn	Spruce, Norway
Sr	Spruce, red
Sw	Spruce, white

Other codes can be developed as required.

5-7 **Block** These entries are used to locate EXACTLY which tree was sampled. They make returning to the same tree easier.

8-10 **Row**

11-13 **Column**

14-19 **Clone/family no.**

20-21 **Cone year:** The year the strobili first appear.

22-34 DATA ON STROBILI

22-24 **Number of strobili (NS):** Number of strobili counted on the sample tree.

25-27 **Number of branches (NB):** Number of branches on the sample tree on which strobili were counted.

28-30 **Total number of branches (TNB):** Predicted total number of cone-bearing branches on the sample tree.

31-34 **Predicted total number of strobili (PTNS):** If all the strobili on a given sample tree were counted, then

PTNS = NS,

otherwise

PTNS = NS x TNB/NB.

35-53 ESTIMATING SEED PRODUCTION PER TREE

35-38 **Sound seed (SS):** Number of sound seed obtained from the cones. Either one line per single cone or a total for the cones (see 39-41 below).

39-41 **Cone number (CN):** This is the number of cones used to obtain the sound seed yield data, e.g., not all the cones on the sample trees will be sampled and have their seed extracted.

42-45 **Seed potential per cone (SPPC):** This value is the number of fertile cone scales times two, e.g., the biological potential per cone. Values for this should be determined for each species and orchard by counting the number of cone scales in the middle two-thirds of the cone. Few good seed is obtained from the scales at the top and the bottom of cones. These values should not vary greatly between clones or families nor between years within a given orchard.

If this information is not obtained, or not known for a given orchard, the following approximate values can be used.

Species	Approx. no. fertile scales per cone
Larch, tamarack	8-10
Pine, jack	55-60
Pine, red	25-30
Pine, white	35-40
Spruce, black	30-35
Spruce, Norway	75-80
Spruce, red	35-40
Spruce, white	35-40

46-49 **Predicted sound seed per cone (PSSC):** The PSSC values are determined based on past seed yield data. For the first sampling year,

PSSC = SS/CN

50-53 **Predicted total number of seeds per tree (PSPT):** Once the total number of strobili on the sample trees has been determined, a PSPT value is calculated:

PSPT = PTNS X PSSC

54-65 ESTIMATING TOTAL SEED PRODUCTION

54-57 **Number of trees (NT):** This is the total number of ramets or seedlings in the orchard or orchard block.

58-61 **Cone size (CS):** Number of cones per litre. This value should be determined for each orchard. Cone size will vary with parent tree, species, and orchard site (fertility).

62-65 **Predicted orchard seed production (POSP):** The predicted orchard seed production (POSP), expressed in thousands of seeds is the cumulative total of all the sample trees. The total count (PSPT) is averaged for all the sample trees and then multiplied by the total number of seedlings/ramets in the orchard.

e.g.,

$$\mathrm{POSP} = ((\mathrm{PSPT1} + \mathrm{PSPT2} + \ldots\ldots\ldots\ldots\ldots\ldots \mathrm{PSPTn})\ /n) \times \mathrm{NT}$$

where:

POSP = predicted total number of seeds from the orchard

PSPT1 = predicted total number of seeds from sample tree 1

PSPT2 = predicted total number of seeds from sample tree 2

PSPTn = predicted total number of seeds from sample tree n

n = total number of sample trees

NT = total number of seedlings/ramets in the orchard.

66-80 CONE AND SEED EFFICIENCY

66-69 **Predicted cone efficiency (PCE):** The predicted cone efficiency is an expected value for a given years's actual cone efficiency (ACE). It is not measured but is the best estimate available based on knowledge of past orchard performance.

We do not as yet have accurate ACE values for Maritime orchards. Cone efficiency values from the southern U.S. (Bramlett and Godbee 1982) are as follows:

ACE	Level of orchard management.
0.70 +	Intensively managed orchards with effective insect control.
0.50-0.70	Moderately managed orchards.
<0.50	Poorly managed orchards or natural stands.

Accurate estimates for ACE will be obtainable only after cone efficiency values have been measured in an orchard for several years. Until that time, the values from Bramlett and Godbee (1982) can be used.

70-73 **Predicted seed efficiency (PSE):** Predicted seed efficiency is the ratio of filled seeds (SS) to the seed potential (PSSC). A similar procedure to calculating PCE is followed.

For the first year of inventory, a "best estimate" should also be used. Again, as there are no values for Maritime seed orchards, suggested estimates are taken from Bramlett and Godbee (1982).

PSE	Level of orchard management.
0.55 +	Intensively managed orchards with effective insect control.
0.35-0.55	Moderately managed orchards.
<0.35	Poorly managed orchards or natural stands.

For subsequent years, PSE values should be obtained from the average of previous years.

74-76 **Estimated extraction efficiency (EEE):** The estimated extraction efficiency measures the percentage of the sound seed removed from the cones.

Orchard predicted extracted seed (OPES): The OPES is based on the results from previous cone analyses and is calculated as follows:

OPES = POSP X EEE

77-80 **Seed use efficiency (ESU):** The ESU is a measure of reductions from the total seed potential, which occur at the nursery. The two main sources are;

77-78 **1. Excess seed usage (ESU):** i.e., two seed sown per cavity without transplanting the extra seedlings.

79-80 **2. Reduced germination (RG):** It is not reasonable to expect 100% germination, hence this figure will be less than 1.0.

The ESU is calculated as follows;

ESU = 100/ESU X RG
e.g., two seeds per cavity; ESU = 2
90% germination; RGE = 0.90

ESU = 100/2 X 0.90 = 0.45

The data from these procedures must be collected accurately and regularly if the productivity of an orchard is to be correctly assessed. When cone life tables (Figure VIII-4) have been constructed, measures can be taken to identify which sources of seed loss are most important, and consequently where to direct preventative measures to best rectify the problem(s).

Figure VIII-3. Seed yield form.

TREE IDENTIFICATION							DATA ON STROBILI				SEED PRODUCTION PER TREE					ESTIMATING TOTAL SEED PRODUCTION			EFFICIENCY				
ORCHARD NUMBER	SPECIES	BLOCK	ROW	COLUMN	CLONE/ FAMILY NUMBER	CONE YEAR	NS	NB	TNB	PTNS	SS	CN	SPPC	PSSC	PSPT	NT	CS	POSP	PCE	PSE	EEE	SUE	
																						ESU	RG
1 2	3 4	5 6 7	8 9 10	11 12 13	14 15 16 17 18 19	20 21	22 23 24	25 26 27	28 29 30	31 32 33 34	35 36 37 38	39 40 41	42 43 44 45	46 47 48 49	50 51 52 53	54 55 56 57	58 59 60 61	62 63 64 65	66 67 68 69	70 71 72 73	74 75 76	77 78	79 80

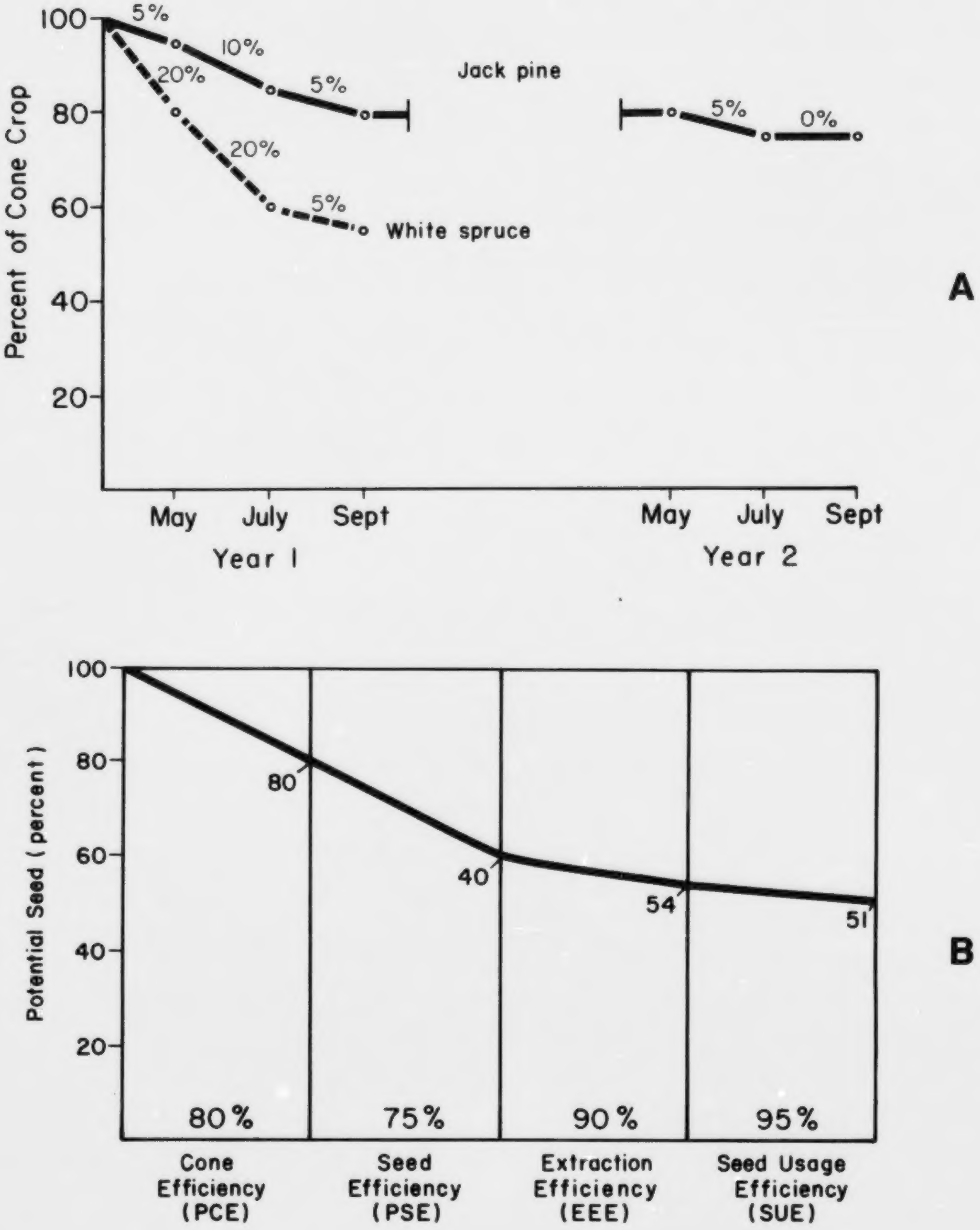


Figure VIII-4. Cone life-tables A - cone efficiency (survival), and B - seed orchard to nursery efficiency (adapted from Bramlett and Godbee 1982).

APPENDIX XI

REPRODUCTION OF CONIFERS

This publication is available free upon request from:

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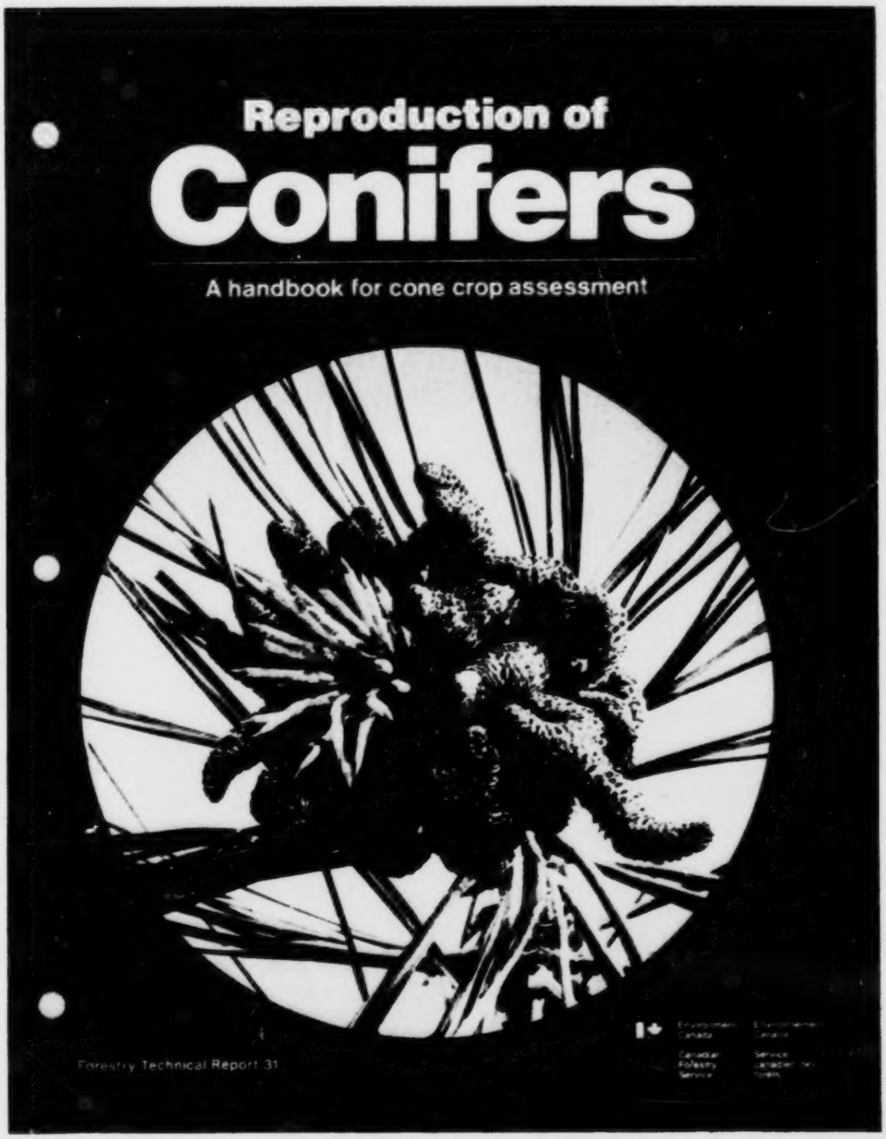
Distribution Centre
151 Jean Proulx
Hull, Quebec
K1A 1C7



Reproduction of
Conifers

A handbook for cone crop assessment

Forestry Technical Report 31

APPENDIX IX

LIST OF INSECTICIDES WITH POTENTIAL UTILITY IN SEED ORCHARDS

Taky (1986)[1] lists some insecticides and their formulations which are registered in Canada which have potential utility in seed orchards under the pesticide Minor Use Program. As most are NOT registered specifically for use in seed orchards, refer to the compendium of registered pesticides (Agric. Can. 1984)[2] for the exact restrictions placed on these chemicals.

The following criteria must be met before a proposal for minor use will be entertained:

1. The pesticide must have been evaluated and registered for other purposes under the Pest Control Products Act.
2. The use must be for a crop or pest for which adequate pesticides are not already registered.
3. There must be adequate reasons, or experience, to believe that the pesticide will be effective for the expressed, intended purpose.

All of the chemicals listed in this section meet these criteria for the target insects given. Recommendations are not given for all insect species on the list (see tables IX-1, IX-2).

[1] Taky, J. 1986. Minor use of pesticides program handbook. Pesticide Information. Special Edition. Agric. Can., Res. Branch. Ottawa.

[2] Agriculture Canada. 1984. Compendium of pest control products registered in Canada: Control of arthropods and molluscs. Agric. Can. Pesticides Division, Plant Health and Plant Products Directorate. 1984.

Table IX-1. Insect species listing cross-referenced with 'potential' control measures

Code	Species	Control Codes (see table IX-2)
A1	*Acleris variana*	
A2	*Adelges abietis*	IV,XII,XV,XVI
A3	*Adelges lariciatus*	
A4	*Adelges piceae*	IV,XV
A5	*Adelges strobilobius*	
A6	*Aphrophora spp.*	
A7	*Asynapta hopkinsi*	
B1	*Barbara mappana*	
C0	*Choristoneura fumiferana*	VI,VII,XII
C1	*Choristoneura pinus*	
C2	*Cinara spp.*	I,IV,V,XII
C3	*Coleophora laricella*	IV,XII,XVI,XVII
C4	*Coleotechnites laricis*	
C5	*Conophthorus banksianae*	
C6	*Conophthorus coniperda*	
C7	*Conophthorus resinosae*	
C8	*Cydia strobilella*	
C9	*Cydia toreuta*	
D1	*Dasineura canadensis*	
D2	*Dasineura rachiphaga*	
D3	*Dendroctonus rufipennis*	
D4	*Dendroctonus simplex*	
D5	*Dioryctria abietivorella*	
D6	*Dioryctria disclusa*	
D7	*Dioryctria reniculelloides*	
E1	*Ectropis crepuscularia*	
E2	*Endopzia piceana*	
E3	*Eucosma monitorana*	
E4	*Eucosma tocullionana*	
E5	*Eupithecia albicapitata*	
E6	*Eupithecia mutata*	
E7	*Exoteleia nepheos*	
F1	*Formica spp.*	III,IV
G1	*Gilpinia hercyniae*	
H1	*Henricus fuscodorsanus*	
H2	*Holcocerina immaculella*	
H3	*Hylemya anthracina*	
H4	*Hylemya viarium*	
H5	*Hylobius spp.*	
L1	*Lambdina fiscellaria fiscellaria*	VI,VII,XII

Code	*Species*	Control Codes (see table IX-2)
M1	*Mayetiola carpophaga*	
M2	*Mayetiola piceae*	
M3	*Megastigmus atedius atedius*	
M4	*Megastigmus laricis*	
M5	*Megastigmus specularis*	
M6	*Mindarus abietinus*	
N1	*Neodiprion abietis*	
N2	*Neodiprion nanulus nanulus*	IV,XII,XIII,XIV,XVI,XVII,
N3	*Neodiprion sertifer*	
N4	*Neodiprion swainei*	IV,XII,XVI
N5	*Neodiprion virginiana*	
O1	*Oligonychus milleri*	
O2	*Oligonychus ununguis*	I,IV,V,VIII,IX,X,XII
O3	*Orgyia leucostigma*	XII,VII
P1	*Petrova albicapitana*	
P2	*Physokermes piceae*	IV,VI,XII
P3	*Pikonema alaskensis*	XII,XIII,XIV,XVI,XVII
P4	*Pineus pinifoliae*	IV,XII,XV
P5	*Pineus strobi*	IV,XI,XII,XIV,XV
P6	*Pissodes strobi*	XII
P7	*Pissodes spp.*	XII,XVI,XVII
P8	*Pleroneura brunneicornis*	
P9	*Pristiphora erichsonii*	XII,XIII,XIV,XVI
R1	*Resseliella spp.*	
R2	*Rhabdophaga swainei*	
R3	*Rhyacionia buoliana*	IV,VI,XVI,XVII
S1	*Spilonota lariciana*	
T1	*Tetyra bipunctata*	
T2	*Toumeyella parvicornis*	XII
X1	*Xyela spp.*	
Z1	*Zeiraphera canadensis*	II,VI,XII
Z2	*Zeiraphera improbana*	

Table IX-2. Products with potential for insect control in seed orchards.

Compound Name		Formulation (rate)	Target insects (see Table IX-1)
I Acephate (orthene) 75 SP			
a) Hydraulic sprayer		40 g/50 L	C3,O2
II *Bacillus thuringiensis* **(dipel, thuricide)**			
a) Hydraulic sprayer		20 g/50 L	Z1
b) Mist blower		45 g/50 L	Z1
III Chlordane 40% WP or EC		Mix into hills	F1
IV Diazinon 50 EC			
a) Hydraulic sprayer	i)	70 mL/50 L	C2,C4,O2,P4,P5
	ii)	85 mL/50 L	A2,P2,R3
	iii)	115 mL/50 L	A5,N2,N4
b) Mist blower	i)	70 mL/10 L	C3,P4,P5
	ii)	115 mL/10 L	A2
	iii)	140 mL/10 L	N2,N4
	iv)	290 mL/10 L	A5
	v)	340 mL/10 L	C2,F1
	vi)	425 mL/10 L	P2,R3
	vii)	570 mL/10 L	A5
V Diazinon 50 WP			
a) Hydraulic sprayer		70 mL/50 L	C2,O2
VI Dimethoate 40 EC		(Cygon 2E,4E Rogor 40), if 2E used double the quantity	
a) Hydraulic sprayer	i)	115 mL/50 L	C0,L1,R3,Z1
b) Mist blower	ii)	140 mL/10 L	Z1
	iii)	570 mL/10 L	C0,L1,P2,R3
VII Dylox 80 SP			
a) Hydraulic sprayer		45 g/50 L	C0,L1,O3
b) Mist blower		225 g/10 L	C0,L1,O3

Compound Name		Formulation (rate)	Target insects (see Table IX-1)
VIII Genite 50 EC			
a) Hydraulic sprayer		85 mL/50 L	O2
b) Mist blower		115 mL/10 L	O2
IX Kelthane 18.5% EC			
a) Hydraulic sprayer	i)	85 mL/50 L	O2
	ii)	140 mL/50 L	O2
b) Mist blower	i)	115 mL/10 L	O2
	ii)	710 mL/10 L	O2
X Kelthane 18.5% WP			
a) Hydraulic sprayer	i)	25 g/50 L	O2
	ii)	85 g/50 L	O2
b) Mist blower	i)	110 g/10 L	O2
XI Lindane 20 EC			
a) Hydraulic sprayer		570 mL/50 L	P5
b) Mist blower		425 mL/10 L	P5
XII Malathion 50 EC			
a) Hydraulic sprayer	i)	55 mL/50 L	P7
	ii)	115 mL/50 L	A2,C0,C2,C3,L1,N2,N4,O2,O3,P2,P3,P4,P5,P6,T2,Z1
b) Mist blower	i)	140 mL/10 L	A2,O2,P3,P4,P5,P8,Z1
	ii)	340 mL/10 L	P6
	iii)	570 mL/10 L	C0,C2,C3,L1,N2,N4,O2,O3,P2,T2
XIII Methoxychlor 50 W			
a) Hydraulic sprayer		100 g/50 L	N2,P3,P8

Compound Name		Formulation (rate)	Target insects (see Table IX-1)
XIV Methoxychlor 24 E			
a) Hydraulic sprayer	i)	290 mL/50 L	P5
b) Mist blower	i)	170 mL/10 L	N2,P3,P8
	ii)	290 mL/10 L	P5
XV Miscible oil (superior dormant oil)			
a) Hydraulic sprayer	i)	1.13 l/50 L	A5
	ii)	1.36 l/50 L	A5
	iii)	1.42 l/50 L	A2,P4,P5
b) Mist blower		Not recommended for use	
XVI Sevin 80S or 85W (carbaryl)			
a) Hydraulic sprayer	i)	60 g/50 L	N2,N4,P3,P7,P8
	ii)	115 g/50 L	A2,C3
	iii)	135 g/50 L	R3
b) Mist blower	i)	70 g/10 L	N2,N4,P3,P7,P8
	ii)	185 g/10 L	A2,C3
	iii)	680 g/10 L	R3
XVII Sevin 50 W			
a) Hydraulic sprayer	i)	55 g/50 L	N2
	ii)	85 g/50 L	P3
	iii)	90 g/50 L	P7
	iv)	185 g/50 L	C3
	v)	230 g/50 L	R3

The information in Table IX-2 was compiled from the following sources.

Agriculture Canada. 1984. Compendium of pest control products registered in Canada: Control of arthropods and molluscs. Agric. Can. Pesticides Division, Plant Health and Plant Products Directorate. 1984.

Brown, N.R.; Amirault, P.A. 1985. Studies on the biology and control of cone and seed insects of selected conifers in the Maritime Provinces. Final Report: Contract No: 08SC.KH209-3-0137 Supply and Services. Canada (for Agriculture Canada) 65p.

Canadian Forestry Service - Maritimes. 1985. Tree Pest Control Leaflets.

APPENDIX X

GROWTH MEASUREMENT TABLE FOR SEED ORCHARD TREES

Instructions for completing Orchard Tree Growth Measurement Table.

Column No.

1-19 TREE IDENTIFICATION

See instructions in APPENDIX VIII.

20-51 NOTES ON TREE DEVELOPMENT

It is important to record the dates of the different stages of tree development. This information can be "tied-in" with weather data and used for operations such as frost protection (Determine if the trees are at a 'frost-sensitive' stage BEFORE an expected heavy frost and then assess if frost protection is necessary).

20-23 Year

24-35 Dates of bud flush

Dates at which MOST of the buds have flushed, e.g., for the spruces, bud cap has separated from the base of the bud.

24-27 Seed cones

28-31 Pollen cones

32-35 Vegetative

36-43 Pollen Shed

36-39 Start: The first date that pollen is released when the buds/branches are shaken.

40-43 End: Pollen shed is deemed as finished when the spent pollen cones start to dry out and little pollen is released when the buds/branches are shaken.

44-51 Data on seed cone receptivity

44-47 Start: Bracts are open

48-51 End: Bracts have closed

52-58 **TREE GROWTH MEASUREMENTS**

52-54 **Leader length (cm)**

55-58 **Tree diameter:** Total tree diameter (mm) at breast height

59-80 **COMMENTS**

Figure X-1. Orchard tree growth and development measurement table.

TREE IDENTIFICATION						NOTES ON TREE DEVELOPMENT								TREE GROWTH		COMMENTS
ORCHARD NUMBER	SPECIES	BLOCK	ROW	COLUMN	CLONE / FAMILY NUMBER	YEAR	BUD FLUSH			POLLEN SHED		SEED CONES RECEPTIVE		LEADER LENGTH (cm)	TREE DIAM (mm)	
							♀ M D	♂ M D	VEG. M D	START M D	END M D	START M D	END M D			
1 2	3 4	5 6 7	8 9 10	11 12 13	14 15 16 17 18 19	20 21 22 23	24 25 26 27	28 29 30 31	32 33 34 35	36 37 38 39	40 41 42 43	44 45 46 47	48 49 50 51	52 53 54	55 56 57 58	59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80

APPENDIX XII

GLOSSARY

Clone: A group of genetically identical plants derived asexually from a single individual by grafting, rooting cuttings or tissue culture techniques.

Cone: One of the reproductive structures of conifers. A female cone or seed cone bears seeds while the male cone or pollen cone bears pollen.

Conelet: An immature female cone of conifers. A young cone from the time following pollination until it has almost attained full size before maturity.

Contact insecticide: A chemical which is toxic to insect(s) directly through contact.

Contamination: The introduction of foreign matter that may alter the behavior of material under observation. e.g., foreign pollen in seed orchards or in single-tree pollens used for controlled pollination.

Controlled pollination: The transfer of pollen from a known tree to the female strobili of another known tree, excluding any foreign pollen.

Cross (noun): The plant resulting when two plants which are different genetically are control pollinated [hybrid]. (verb) To cross-pollinate [hydridize].

Cutting: Detached portion of leaf, stem, or piece of root which is encouraged to form roots thus producing an entire plant.

Differentiation: See primordium.

Embryo: The portion of the seed resulting from the union of male and female gametes which develops into a mature plant.

Family, full-sib: The offspring of a single pair of trees, usually resulting from controlled pollination.

Family, half-sib: The offspring of a single tree (usually female parent) having different parents of the other sex. A half-sib family may result from open pollination or from controlled pollination using a mixture of pollen.

Family test: Evaluation of groups of open-pollinated seedlings originating from separate plus trees. The information is used to rogue seedling seed orchards and to indicate superiority of the plus tree if so desired.

Gamete: The single male cell (pollen) and female cell (egg) which form the zygote that develops into the embryo.

Gametophyte: (in a coniferous seed) Food storage tissue contained in the seed and surrounding the embryo.

Genotype: The entire genetic constitution of an individual.

Genotype-environment interaction: The reaction of trees from different families or clones to various external stimuli. e.g., fertilizer, climate.

Graft: The completed or successful union of a detached branch (scion) with a rootstock.

Graft incompatibility: A failure of the scion and rootstock to maintain a successful union due to physiological factors.

Initiation: See primordium.

Megastrobilus: The reproductive structure on conifers which bears seed i.e., the seed cone.

Microstrobilus: The reproductive structure on conifers which bears pollen i.e., the pollen cone.

Open pollination: Natural pollination effected by wind or insects and not influenced directly by man.

Ortet: The orginal ancestor of a vegetatively propagated clone.

Outcrossing: To mate (cross) unrelated individuals.

Panmixis: Random cross-pollination.

Phenotype: The result of the interaction between genetic make-up of an individual (genotype) and the environment. The tree as we see it.

Pollen cone: The male reproductive structure on conifers which bears pollen.

Pollen dilution zone: An area adjacent to or surrounding a seed orchard within which most foreign pollen will settle out.

Pollination: The act of bringing pollen into close contact with a receptive female strobilus.

Primordium (pl. primoridia): A microscopic mound of tissue (group of cells) at its earliest stage of development of an organ, e.g., bud primordium, leaf primordium. Two phases of development are involved. During the initiation phase, the mound of tissue forms. The differentiation stage occurs later when the tissue develops into a particular type of bud (vegetative, pollen cone, or seed cone), or it may not differentiate and remain latent.

Progeny test: Evaluation of a parent (or parents) from the performance of its (their) offspring (progeny). The seed from these tests is usually derived from controlled pollinations.

Progeny: The offspring of a particular tree or pair of control pollinated trees.

Ramet: An individual member of a clone resulting from vegetative propagation.

Rogue: To systematically remove undesirable individuals from a seed orchard.

Rootstock: A seedling onto which a scion is grafted.

Scion: A detached part of a plant grafted onto a rootstock.

Seed cone: The female reproductive structure of conifers which bears seeds.

Seed orchard: An artificial population of trees, isolated to reduce influx of genetically inferior pollen and intensively managed to produce early, frequent and abundant cone crops.

Seed orchard, clonal: A seed orchard composed of vegetatively propagated trees (grafts/rooted cuttings).

Seed orchard, seedling: A seed orchard composed of seedlings.

Seedlot: A group of seeds used to describe a collection from a single tree, group of trees, seed orchard block, etc.

Self-pollination: The pollinaton of a female strobilus with pollen from the same tree or clone.

Sound seed: Those seed full of viable tissue.

Strobilus: (pl. strobili): One of the reproductive structures of conifers. A female cone or megastrobilus bears seeds while the male cone or microstrobilus bears pollen.

Systemic insecticide: A chemical, when applied either externally or internally to various parts of a tree, is absorbed and translocated to untreated plant tissue, rendering the tissue toxic to insects.

Topophysis: A physiological condition whereby a grafted scion continues to grow in a branch-like habit instead of upright.

Viability: The capacity of a seed to germinate.

The following references were consulted to compile this glossary.

Anonymous. 198 . Management techniques for seed orchards. Ontario Min. Nat. Res., Tree Seed and Forest Genetics Unit., Draft.

Snyder, E.S. 1972. Glossary for forest tree improvement workers. USDA, For. Serv., South. For. Exp. Sta., New Orleans.

Wright, J.W. 1976. Introduction to forest genetics. Academic Press Inc., New York.